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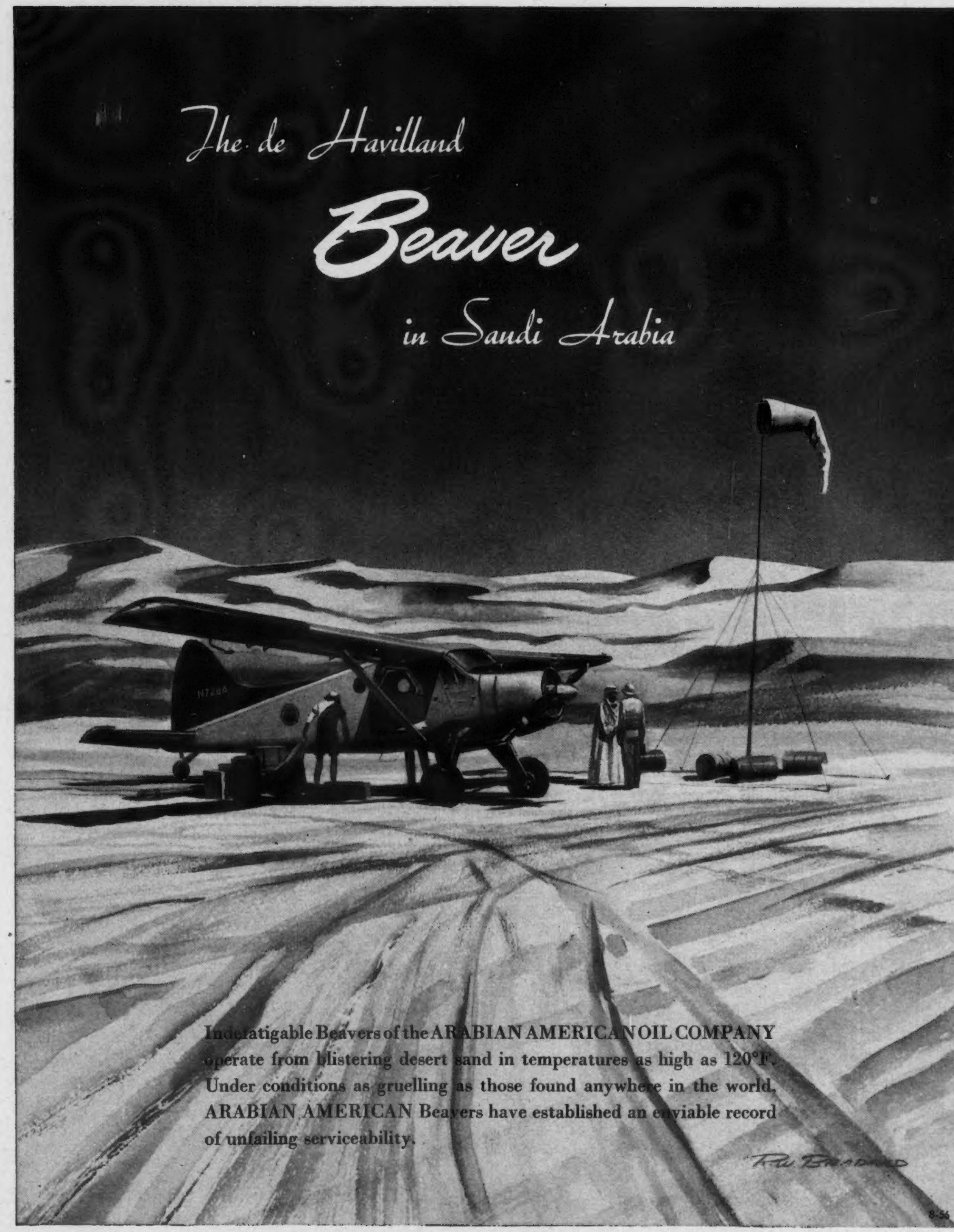

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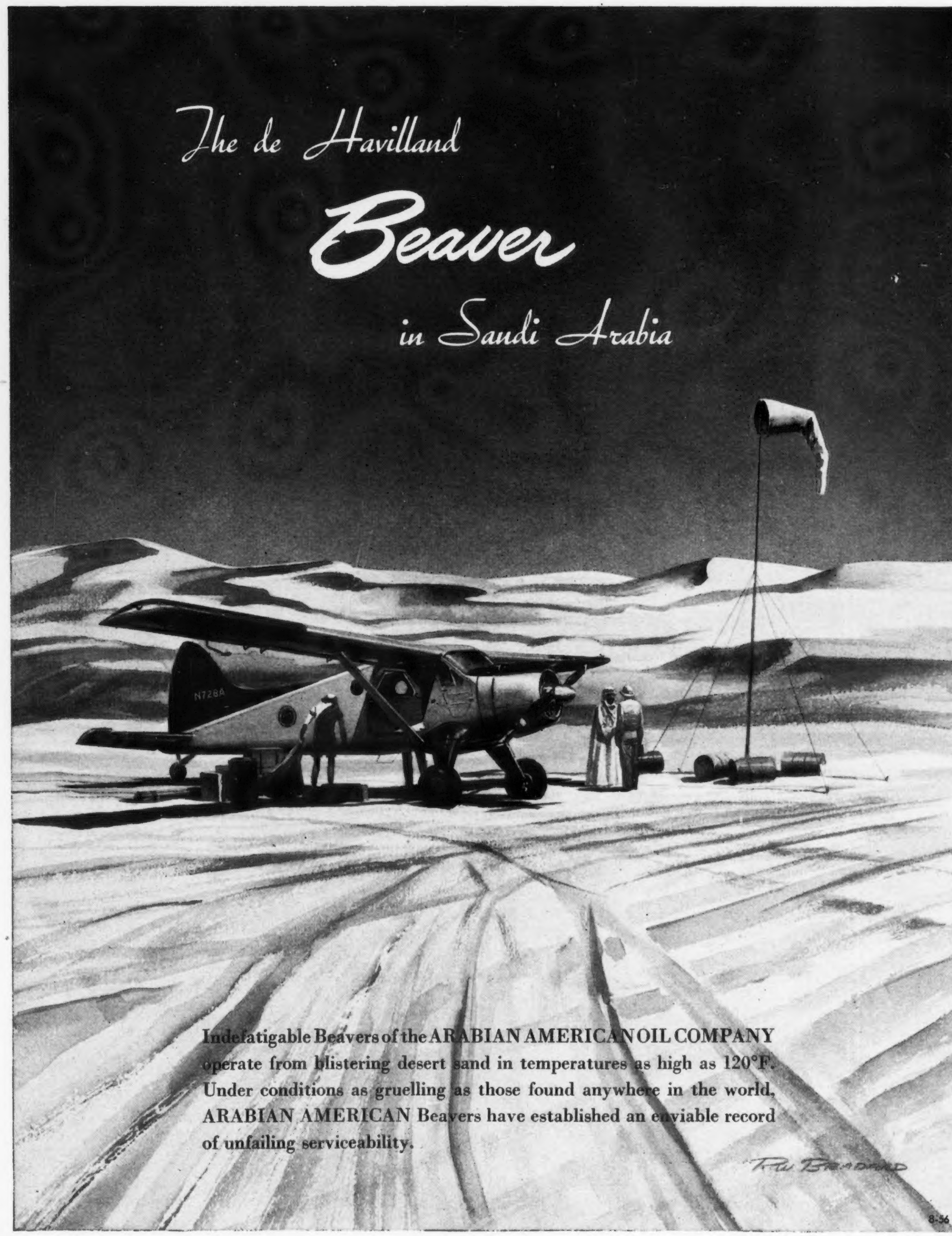
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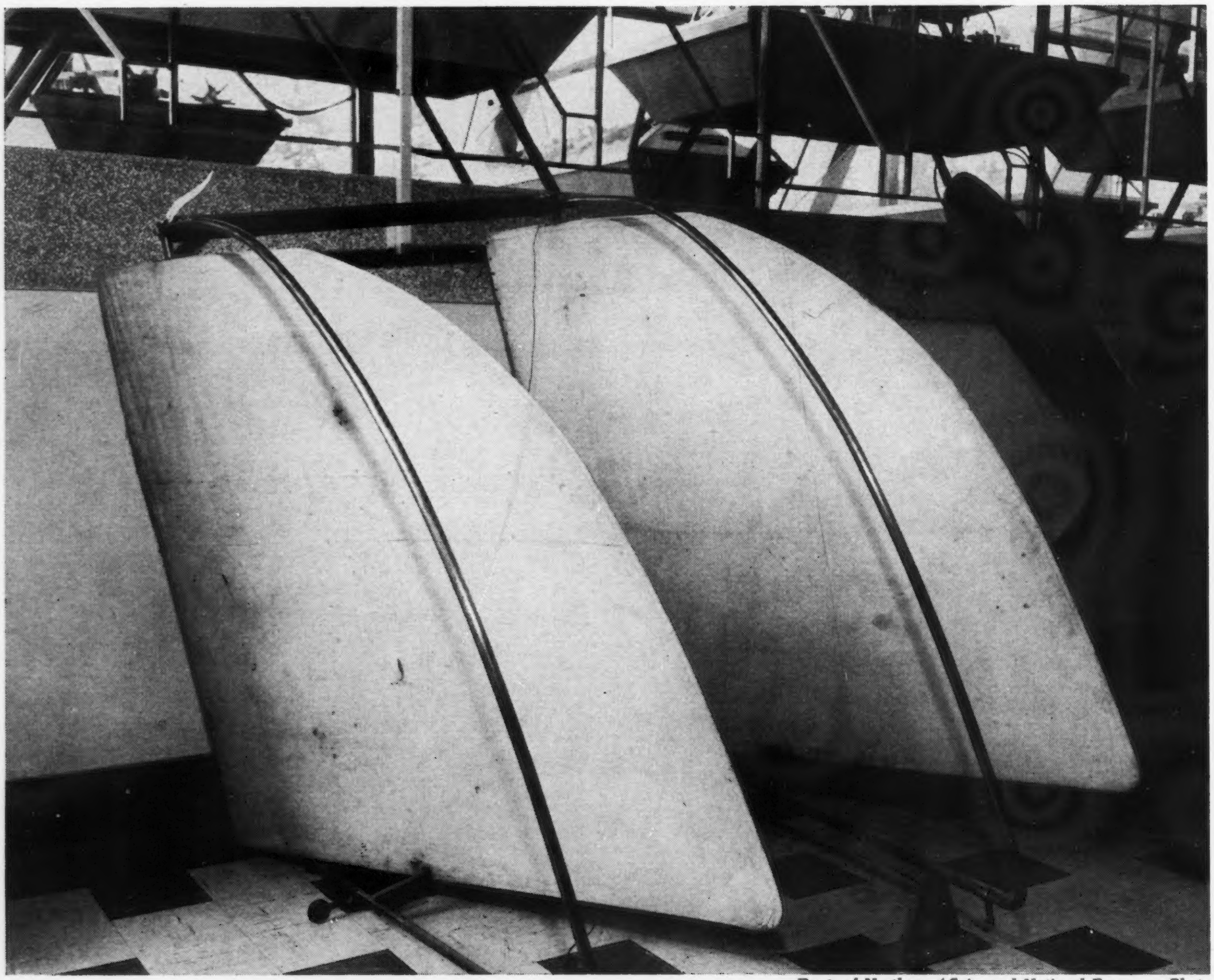


Dept. of Northern Affairs and National Resources Photo

Probably the oldest ailerons still in existence. They are from the Baddeck II, built by the Canadian Aerodrome Company in 1909. (See page 234.)

EDITORIAL

AIR TRAFFIC CONTROL

AIR traffic control, now and in the jet future, is a subject of more than ordinary interest to the air industry. The solution of its problems would seem to offer a worthy challenge to initiative, the ingenuity and the skills of aviation's technical brainpower.

In Canadian terms, our appraisal of the traffic situation should be modified to recognize our relatively light airway and terminal congestion, compared with the United States. It should also be noted that the Department of Transport has shown considerable enterprise in the current program to install surveillance radar at the major terminals. It would seem logical to extend this policy eventually to cover all control tower airports in the counrty.

At the most heavily congested Canadian terminals, it would appear to be presently desirable, and soon essential, to provide a greater number of holding patterns, with increased use of electronic aids to monitor these.

Another most important measure for continued air traffic safety is the creation of satellite airports to permit separation of lightplane, military and airline traffic at the major terminals. Related to this is the sensible proposal that two-way radio should be mandatory for all aircraft operating within controlled airspace in Canada.

Under present conditions, there is no safe substitute for cockpit vigilance and this is a responsibility of every pilot in flight.

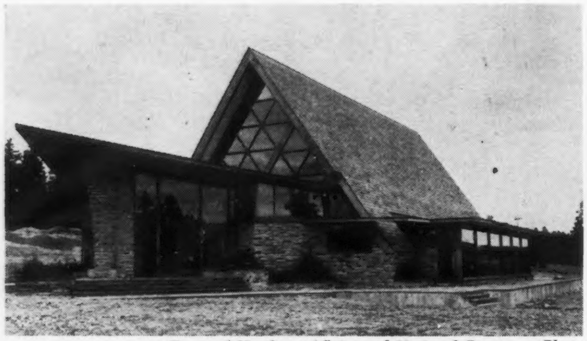
The time will soon come, however, when the increased speeds of airliners will require complete reliance on electronic and automatic aids. Consider, for example, the fact that the 600 mph aircraft will be approaching bullet speed. Two such aircraft on a head-on collision course would be doomed, since it would be impossible for the pilots, relying on vision, to recognize the danger in time to take avoiding action.

The relentless increase in speeds and in the density of air traffic will demand a high degree of automation in air traffic control. It is this situation which will call for miracles of technical achievement. The present cumbersome voice-communication must be replaced by instantaneous, automatic indication in cockpit and control tower. It is conceivable that the airways will require a high-altitude equivalent of the railway block control system, with a green light in the cockpit to clear an airliner into the next airspace segment.

I would not suggest that the jets will require different control equipment or handling technique. It has already been established that they can operate normally in the piston patterns. But I would commend to the technical fraternity the challenging problem inherent with the new speeds and the growing density of air traffic.

G. W. G. McConachie
President
Canadian Pacific Air Lines, Ltd.

ALEXANDER GRAHAM BELL MUSEUM



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The Alexander Graham Bell Museum Baddeck, N.S.

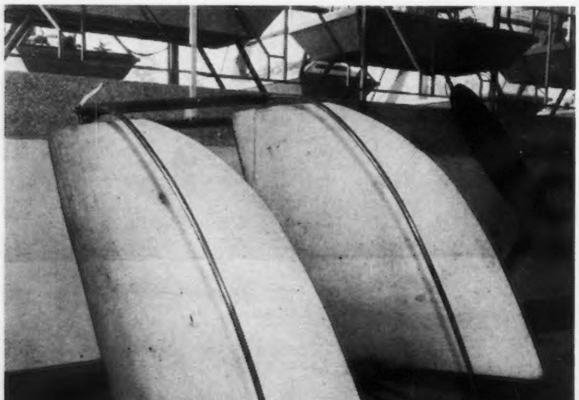
National Geographic Society Photo

The Aerial Experiment Association: (l to r) G. H. Curtiss, J. A. D. McCurdy, Dr. A. G. Bell, F. W. (Casey) Baldwin and Lt. T. E. Selfridge.

On the 18th August Mrs. Gilbert Grosvenor and Mrs. Daniel Fairchild, daughters of Dr. Alexander Graham Bell and now living in Washington, D.C., opened the new Alexander Graham Bell Museum at Baddeck, Nova Scotia. The museum had been built by the Department of Northern Affairs and National Resources to house a collection of scientific material left by Dr. Bell and recently presented to Canada by his family. The Honourable Jean Lesage, Minister of Northern Affairs and National Resources, and the Honourable J. A. D. McCurdy, the last surviving member of the Aerial Experiment Association, also spoke at the ceremony.

Apart from his work on the telephone and inventions in many other fields, Dr. Bell did a great deal of research in aeronautics, particularly with kites. When his work with kites had reached a stage where he required engineering assistance, Dr. Bell elicited the help of two young engineers, J. A. D. McCurdy and F. W. (Casey) Baldwin, and with them and Glenn Curtiss, an American engine expert, and Lt. Tom Selfridge, a U.S. Army expert on "aerodromics", formed the Aerial Experiment Association in 1907. The Associaton was financed by Mrs. Bell. They built five aircraft, including the Red Wing, in which Mr. Baldwin made the Association's first flight (and the first flight by a Canadian) at Hammondsport, N.Y., on the 12th March 1908, and the Silver Dart, in which Mr. McCurdy made the first flight by a British subject in the British Empire, at Baddeck on the 23rd February 1909. In March 1909 the Association was dissolved and replaced by the Canadian Aerodrome Company; the Company built five more aircraft including the Baddeck II, the ailerons of which are still extant. The invention of the aileron was perhaps the Aerial Experiment Association's most important contribution to aeronautics.

Hitherto most of Dr. Bell's relics and records have been lying in the "Kite Shed" on his estate at Baddeck but they were in no particular order and in serious danger of destruction by fire. This valuable collection is now properly housed and displayed as a fitting memorial to his inventive genius.



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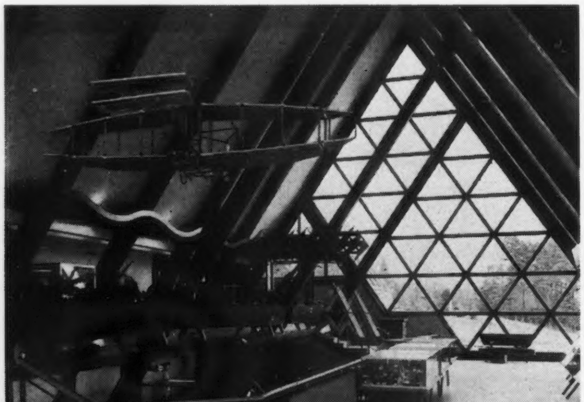
Ailerons of the Baddeck II



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Interior of the Museum, including a model of the Silver Dart

LIFT AND THRUST CREATING SYSTEMS— THEIR APPLICATION TO SHORT- AND VERTICAL-TAKEOFF AIRCRAFT†

by F. C. Phillips* and K. Irbitis**

Canadair Limited

SUMMARY

The principle of lift- and thrust-producing systems is examined; the basic systems are found to be the wing, the ramjet and the rocket. The latter is not considered further on the grounds of being relatively uneconomic in vehicles operating within the atmosphere, i.e. aircraft. The relationship between the wing and ramjet is shown. The possible motions of the wing are examined and the whole family of wing-related thrust-producing systems is discussed, starting with the rotor and ending with the turbojet. High-lift modifications of the fixed wing — flaps, slats and boundary layer control — are also looked into.

Consideration is given to applications of these systems to design of various vertical-takeoff-and-landing (VTOL) and short-takeoff-and-landing (STOL) aircraft. Advantages and limitations of these aircraft types are discussed. This study shows in particular that:

(*a*) the pressure jet helicopter is apt to be the most efficient type as regards payload for VTOL short-range low-speed applications,

(*b*) the slipstream-deflection airplane, basically an STOL type, can approach the pressure jet's payload efficiency at short range, can show good efficiency over longer ranges, and can cruise at speeds up to 500 mph,

(*c*) at speeds between, say, Mach number 0.7 to 2.0, where aerothermal effects grow to become dominant, the VTOL coleopter type is capable of short range. The VTOL flying disk may in addition be able to demonstrate longer range capability because of greater fuel storage, and

(*d*) at still higher speeds in the atmosphere only very simply shaped vehicles can withstand the aerothermal effects. The disk and the longitudinally-elongated lifting body would typify such aircraft.

Aside from several exceptions, it would appear that VTOL and STOL capability would be so expensive in terms of range-load potential as to preclude it except when required by the nature of the aircraft operation. Nevertheless, increased application of VTOL and STOL techniques should not be overlooked as a means of designing better aircraft.

INTRODUCTION

ONE finds himself reading without shock these days of airplanes demanding thick, wide, concrete runways almost two miles long. What a tribute to piloting skill and human organization — that we can consider fighting a war, or enjoying an intercontinental jet-powered holiday, through the use of such a vehicle!

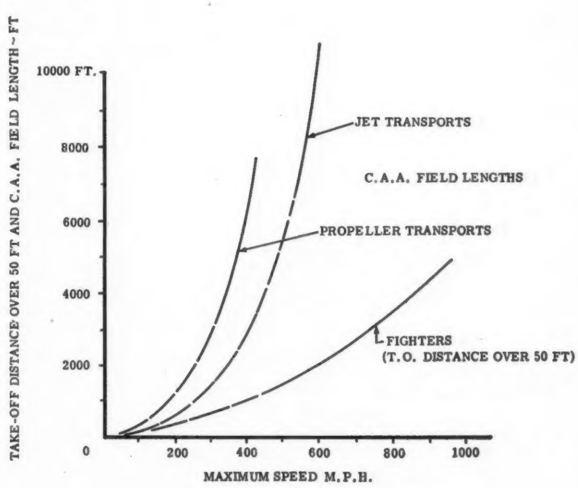


Figure 1

Take-off distance vs maximum speed

It would appear that our preoccupation with high speed has deadened the ability to respond to a really serious aeronautical problem — the "real estate" problem. Observe the tremendous growth of takeoff distance, for example, as top speed has increased over the recent past (Figure 1). These data are standard-condition aircraft demonstration data. For the transports, CAA operational runway length is quoted on the basis of engine failure at the critical point; for the fighters, a sizable allowance for operational contingencies must be added for hot day, engine malfunctioning, pilot error and other effects. Certainly then we must admit that the airport engineer can take some of the credit for breaking the speed barriers.

Recently, as we have seen, the takeoff and landing distance problems have been receiving some serious attention. In the first place, airport size for modern high-speed airplanes has become so great that the magnitudes have forced our attention. Further, the helicopter has demonstrated vertical takeoff to be so advantageous that we are pressed to incorporate it in a vehicle with the potential of high forward speed. And so we have on the drafting boards a host of potential solutions to

†Paper read at the Annual General Meeting of the C.A.I. in Montreal on the 4th May, 1956.

*Chief of Aerodynamics and Preliminary Design.

**Preliminary Design Engineer.

airport size difficulties, falling into the headings of vertical-takeoff-and-landing (VTOL) or short-takeoff-and-landing (STOL) aircraft. Because of the current interest in such aircraft, and because of their particular appeal to us in Canada, this paper proposes to examine the principles of lift- and thrust-producing systems and their application to VTOL and STOL aircraft.

BASIC LIFT- AND THRUST-PRODUCING SYSTEMS

General Remarks

There are two fundamental methods used in aeronautics to produce a force for overcoming the earth's gravitational pull and/or the drag of a vehicle in motion. Both are based on Newton's Third Law (action and reaction are equal and opposite), which in its usual form relates force, mass and acceleration: $F = -m\ a$. If one prefers he can replace mass, m, by w, the weight, divided by the acceleration of gravity, g.

By being more fundamental in our view of the Third Law, we arrive at a more convenient form for our purpose: $F=-\left(\frac{dm}{dt}\right)v$, which states that mass handled per unit time, multiplied by the velocity steadily imparted in a certain direction, is equal to the reactive force in the direction opposite to the velocity. Insofar as the Law is concerned, the mass handled by the system – for example one producing lift or thrust – may be that of the medium flowing past or through it, or it may be mass belonging to the system itself. Note that the force may be the product of a large mass flow and a small imparted velocity, or vice versa. The efficiency of the system is much concerned with the separate magnitudes of mass flow and velocity, but not the force itself.

Use of External Mass

If we consider force creation by imparting velocity to mass external to the system, we are depending on the atmosphere to furnish the mass and so are restricted in our consideration to the airspace. We can operate on the air by dynamic or thermal means, hence we have basic aerodynamic and thermodynamic approaches.

External mass flow presumes relative motion between the system and the air about it.

Wing

A body alone moving through the air experiences a drag or negative thrust because air viscosity causes a resultant decrease rather than an increase of velocity in the direction of motion. Any body inclined sufficiently to the flow will deflect the airstream so as to impart some downward velocity, and thus will produce lift. In the special type of lifting body we call a wing (Figure 2A), we use a slender shape and a longish span to reduce drag. The long span handles more air per unit time, which reduces the required downward velocity for a given lift; this in turn reduces the final kinetic energy increase of the air, which is a loss to the system paid for in the form of (induced) drag.

The wing, then, is a fine lifting device but cannot maintain steady, level flight unaided because of an unbalanced drag. Steady flight can obtain if the flight path is inclined downward so that a weight component acts forward along it as a thrust to counteract the drag. Here we have the glider; its flight path angle relative to the air mass is simply the lift-to-drag ratio.

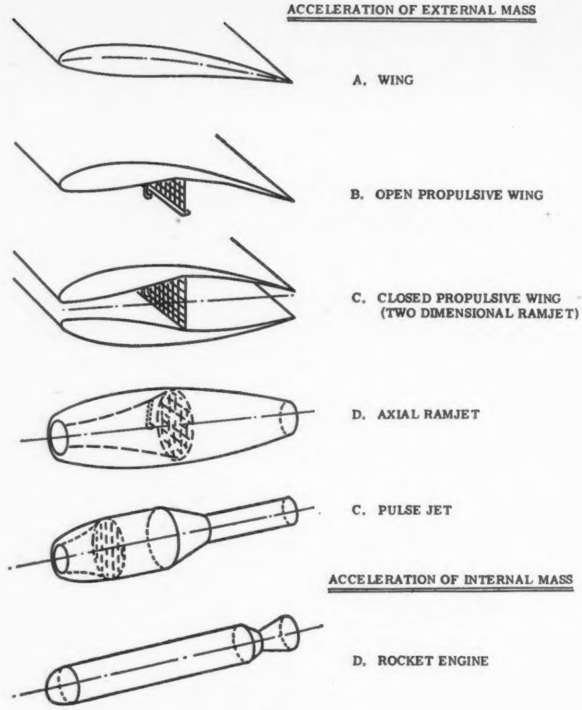


Figure 2
Basic Lift and propulsion systems

Open Propulsive Wing

How can the drag of a basic wing be nullified in the simplest possible manner, using external mass flow? We must increase the axial velocity of the airstream to create a thrust, which can be done by the addition of heat energy. If we violate the external mass principle very slightly to allow the addition of a negligible mass flow of fuel, then burning the fuel in the external airflow would bring about a self-contained thrust-lift system. The wing, plus fuel nozzles and flameholders in a low-velocity, high pressure region of the wing flow, would constitute this simple system (Figure 2B). Considerable airspeed is necessary for this system to function and to attain any degree of economy.

Closed Propulsive Wing (Two-dimensional Ramjet)

Arranging two open propulsive wings to obtain a closed propulsive flow system, we obtain better thermodynamic efficiency and control. This system, given an angle of attack, provides lift and thus the closed propulsive wing (Figure 2C) is self-contained. A ramjet being developed by Marquardt in the U.S.A., for installation at the tip of a helicopter rotor, is in section essentially this device.

Axially-Symmetric Ramjet

If we make a body of revolution of the open propulsive wing, we have the ramjet (Figure 2D). While the geometry has advantages, the ability to handle large mass flows comparable to the wing is gone and the lifting efficiency is poor.

The pulse jet (Figure 2C) is an intermittent ramjet with a spring-loaded valve system, whereby combustion pressures extend upstream and close off the entering air

momentarily. The sub-pressure following combustion causes the valve to open and the chambers fill with air for a new combustion cycle. The pulse jet can produce static thrust since it obtains a mass flow by the sucking action of the sub-pressure.

Use of Internal Mass

Here we consider a force, created by imparting velocity to a mass flow, that is entirely a part of the system. The energy source would be a fuel burned by a self-contained oxidizer. This is the rocket engine (Figure 2D). The system is independent of the atmosphere and forward speed. Since the amount of mass is limited and the exit velocity high, duration and efficiency at subsonic speeds are low.

Summary Remarks

When very high speed is the prime requirement, the rocket engine is attractive since it furnishes the required high thrusts beyond the atmosphere, where fantastic speed is possible. With high thrust/weight ratio and no need for wings, the rocket craft can use its engine for direct lift from zero speed and thus the rocket engine makes such a craft a feasible system. Within the atmosphere, the rocket engine is of advantage only for providing short bursts of high thrust at little complication, as in the jet-assisted-takeoff (JATO) application.

Since it requires forward speed and has poor lifting efficiency, the axial ramjet cannot be a self-contained flight system and tends to be inflexible in application. The propulsive wings, which have better lift possibilities, are more promising but still require assistance until high speeds are reached.

The wing, as we know well, has been used in a variety of applications. Its required separate power source can be any of a number, depending on the mode of wing movement. The types of motion can be classified as:

(*a*) Translatory (straight line) motion.

(*b*) Non-translatory motion.

Since the wing in non-translatory motion can be used to produce the thrust needed for the translating wing, it is more convenient to discuss non-translatory motion first.

WING IN NON-TRANSLATORY MOTION

General Remarks

The simplest motion in this category is pure rotation. However, between pure rotation on the one hand and pure translation on the other, there can be various intermediate non-translatory motions (Figure 3). There is a possibility of oscillatory motion, rotary motion and the combination motions: oscillatory-translatory, oscillatory-rotary and rotary-translatory. Note that in oscillatory motion to create a force in the plane of oscillation, it is necessary to cycle the wing about a spanwise axis during the harmonic oscillation. This superimposed cyclic pitch motion – increased pitch during the down beat – makes possible an average force greater than zero during the cycle. This cyclic pitch change, if used in oscillatory-translatory motion, can bring about a propulsive force component. In rotary-translatory flight, cyclic pitch, which can again create a propulsive force, is needed for lateral control.

The above motions do not include various possible ramifications. For example, the oscillatory-translatory motion can be approached by a rotation of the wing about an axis parallel to its span (if combined with cyclic pitch, the Schneider-Voith propeller). If the wing tip describes an oval, rather than the up-down beat of oscillatory-translatory motion, we have with cyclic pitch, an approximation of bird flight. Further, helicopter blade motion can be taken as rotary-oscillatory-translatory motion combined with cyclic pitch.

Rotor and Propeller

The most convenient mechanical motion of the above type is the rotary one and hence the rotary-wing is very common. Utilized to produce thrust by orienting its axis of rotation roughly parallel to the flight path, it is the propeller; the orientation is such that cyclic pitch is unnecessary. Used primarily for lift and hence with axis normal to flight path, it is the rotor; cyclic pitch is needed for satisfactory operation in forward flight.

Simultaneous ("collective") pitch control, together with driving power control, is used to vary the force output. The power required to turn the rotor or propeller may be supplied through a shaft driven by a piston or gas turbine engine; in this event provision must be made against the reaction to the transmitted torque. The torque reaction problem, which is difficult in the rotor, has been practically eliminated in some examples by mounting ramjets, pulse jets or pressure jets at the blade tips (the pressure jet emits a high-velocity stream like a ramjet but its air supply is furnished by a means of compressing air that is part of the system; fuel may or may not be burned in the process).

The power sources can be rated as to efficiency (power per unit fuelflow) roughly as follows: piston

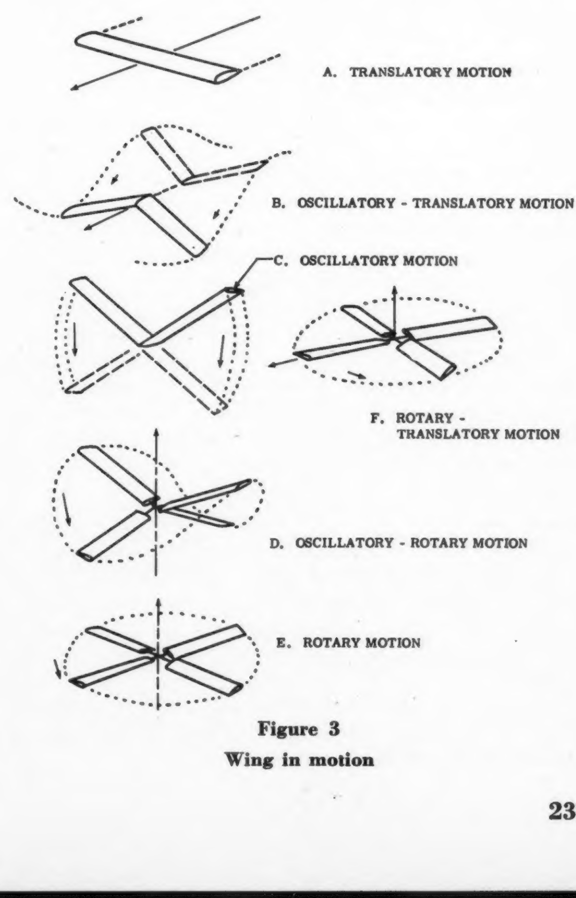


Figure 3
Wing in motion

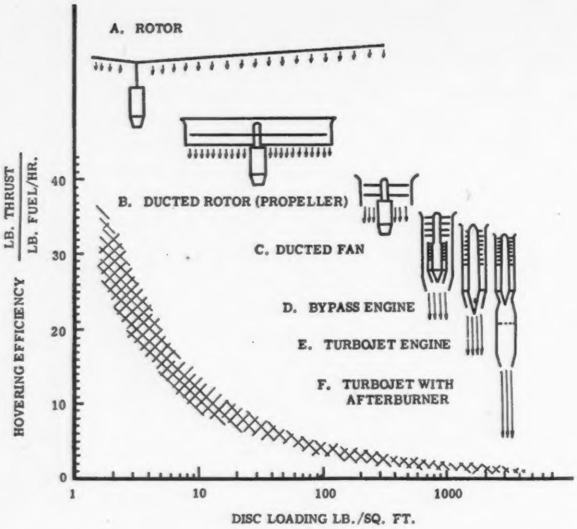


Figure 4

Rotary thrust systems

engine, turbine engine, pressure jet, pulse jet, ramjet. Unfortunately the powerplant weight per unit power is in approximately the same order!

Just as a wing without propulsion can generate lift by giving up altitude, the rotor under proper conditions will autorotate while descending by absorbing energy from the airstream and thus provide lift. Helicopters depend upon this to provide safety in the event of power failure. Since the sinking speed required for safe autorotation is dangerously high, unless the excess kinetic energy of the slipstream is kept to a small value, rotors for especially single-engine helicopters must be large, i.e. have low disk loadings (lift per unit swept area). See Figure 4A.

Ducted Rotor

The lifting wing incurs drag because of lost energy in the tip vortices, which are the result of a secondary flow from the bottom surface high pressure area, around the tip to the top surface low pressure area. Just as end plates on the fixed wing, a fixed shroud surrounding a propeller or rotor (Figure 4B) will reduce the tip losses. Thus, for a given diameter and power input, the thrust may be increased by something in the order of 25% or the diameter at fixed thrust reduced correspondingly.

Flaring the entering side of the shroud to form a bellmouth is important. Adjustment of the exit area by means of flaps is a convenient means of varying lift. The driving torque must be compensated, for example by fixed contravanes, unless contra-rotating rotor pairs are employed.

Ducted Fan

If the ducted fan is distinct from the ducted rotor, it is because of the use of higher disk loadings, which tends to require contra-rotating rotors. If a turbine engine were the prime mover, the exhaust reaction would contribute appreciably to the total force output. See Figure 4C.

Use of a ducted fan, driven by a single engine to provide lift, would be unsound because of the inability to autorotate safely.

Bypass Engine

By completely integrating the ducted fan and the prime mover, by using higher disk loadings and multistage fans (which are now potent enough to be called compressors), by leading a portion of the fan slipstream through a high-pressure compressor and thence through combustors and turbines, we arrive at the bypass engine (Figure 4D).

The high-pressure air flows into combustion chambers where fuel is added and burned. The products of combustion give up some of their energy to the turbine section which drives the compressors. A jet reaction is obtained from the exhausted products of combustion, as well as from the flow by-passed around the second compressor. The engine is named for the feature of the by-pass.

It is interesting to consider the turboprop-propeller combination as a degenerate bypass engine.

Turbojet Engine

Consider a bypass engine where the first compressor has shrunk to the point of zero bypass flow, or has been eliminated altogether. This is the turbojet, two-spool and single-spool types, respectively (Figure 4E).

Turbojet with Afterburner

The present state of the propulsive art is such that much more air is used in the engine than is required for complete combustion of fuel, because otherwise even the best turbine metals available could not withstand the temperatures obtaining. Air-fuel ratios of the order of 100:1 are currently used, as against about 14:1 needed for complete combustion. There being tremendous excess oxygen in the exhaust, it is possible to elongate the tailpipe, add a flameholder and fuel nozzle, and thus burn additional fuel to augment thrust up to about 50% (Figure 4F).

Note that the afterburner operates in essentially the fashion of the ramjet. Since the combustion takes place at relatively low temperatures and pressures, the process is inefficient and fuelflow is correspondingly high.

Comparison of Rotary Systems

Figure 4 shows the various rotary systems together with the order of disk loading currently used; disk area is taken here as total area swept out by the largest rotor involved. The disk loading for a given system is given its magnitude by the intended use — the helicopter rotor to give good autorotative and hovering performance, the turbojet engine to give large thrusts per unit frontal area at high speeds.

Thrust output at zero speed in free air per unit fuelflow is used in Figure 4 to rate the systems for applicability to VTOL and STOL aircraft. Naturally the low-disk-loading rotor is markedly superior because it minimizes slipstream kinetic energy. The turbine engines, being out of their element, are very inefficient; the afterburning turbojet of disk loading 2000 lb/ft^2 will have a hovering thrust per unit fuelflow of only about 0.6 lb/lb fuel per hr.

In fairness, one must keep in mind the advantage of the turbine engines in thrust per pound of weight. Whereas the rotor plus propulsive system of a conventional helicopter can produce about 3 lb thrust per pound of weight, the afterburning turbojet is capable of perhaps a figure of 6 or 7 for a long-life engine.

If one were to calculate the weight of system, plus fuel required to hover for a specified period of time, he would have a true framework of comparison in this connection. The outcome of such a study would be that, with a very short specified hovering time, the turbine engine systems might be attractive. If in the bargain high speed flight is required in the aircraft, then the rotor would be eliminated for a variety of reasons — compressibility, stall, vibration, blade flapping instability. It must be realized, however, that an aircraft with turbine engine system used for direct lift would be of very limited operational utility as regards payload.

WING IN TRANSLATORY MOTION

Propulsive Means

Aside from gliding flight, it is necessary to supply a thrust to the basic wing for sustained straight flight. Since flight must start from rest, the ramjet propulsive wings and ramjets are inadequate unless combined with other thrust-producers, for example rockets or catapults or one of the rotary systems described above.

The efficiency and adaptability of the rotary powerplants ensures that they will remain with us for a long time. Since the variable-pitch propeller delivers for fixed power input an increasing thrust as speed reduces, it demands particular consideration in VTOL and STOL applications; in combination with the turboprop engine, it provides a system with high force output per unit weight combined with very reasonable fuel economy, below speeds of the order of 500 kts.

Takeoff and Landing Distance Parameters

Since much of this section applies particularly to STOL, a very brief outline of the takeoff and landing distance problem of the conventional airplane is justified.

In takeoff the airplane must accelerate from rest to a speed at which the lift capability is in excess of its weight, then leave the ground and assume an upwardly-inclined flight path. Usually the distance required from start to an altitude of 50 ft is used as an indication of operational airport size. Engine failure in a multi-engined airplane may be assumed at a critical point, so that the distance from start to stop in the event of an aborted takeoff becomes of interest.

The parameters at work in takeoff are well illustrated by the equation for the ground run, which constitutes perhaps three-fourths of the total distance:

$$S_G = \frac{V^2_{t.o.}}{2\bar{a}} = \frac{W/S}{(\rho g)\, C_{L_{t.o.}} \left(\frac{\bar{T}_{ex}}{W}\right)}, \text{ where}$$

W/S = wing loading (lb/sq ft)

ρg = weight density of air (lb/cu ft)

$C_{L_{t.o.}}$ = aircraft lift coefficient in condition of liftoff

$\frac{\bar{T}_{ex}}{W}$ = excess of thrust over sum of rolling resistance plus drag; ground run attitude; mean condition (about 70% of takeoff airspeed); expressed as decimal part of gross weight.

We can see directly the bad effects of high wing loading, takeoff altitude and low thrust/weight ratio. The take off lift coefficient $C_{L_{t.o.}}$ is a safe percentage of the stalling coefficient $C_{L_{max}}$. The designer attempts to achieve a high $C_{L_{max}}$ value by means we shall consider, but is usually frustrated in achieving short takeoff since the wing loading is usually excessive to favor high speed flight. But even if a reasonably short total takeoff distance is achieved, to reduce it further to the order talked of in STOL work (for example, 500 ft or less), in the case of a conventional reasonably fast airplane, probably means impossible aerodynamic and other complications. The reasons for this will be seen subsequently.

The landing ground run can be expressed by the same equation as above. However, here high drag is helpful so high $C_{L_{max}}$ values are more readily achieved. On the other hand high thrust/weight ratio, which helps so much in the case of the high-speed fighter takeoff, is of no use in landing unless reverse thrust devices are a design feature.

High-Lift Systems

Oftentimes all factors affecting required runway length are fixed for the designer by other considerations, except the maximum lift coefficient. $C_{L_{max}}$ can be increased by airfoil camber increase, which increases lift at a gven angle of attack, and/or by control of boundary layer flow, thus increasing lift at both a given angle of attack and the maximum (stall) value.

Camber

The idea of camber is to impart downward velocity to the airstream more efficiently. A well-cambered airfoil deflects the air downwards in positive fashion but yet gently enough that the flow follows the profile without separating. At higher angles of attack there is inevitably flow separation from the top surface (Figure 6A) and the lift coefficient consequently reaches a peak value. Unfortunately airfoils having satisfactorily high lift potential also have such large profile drag, at angles of

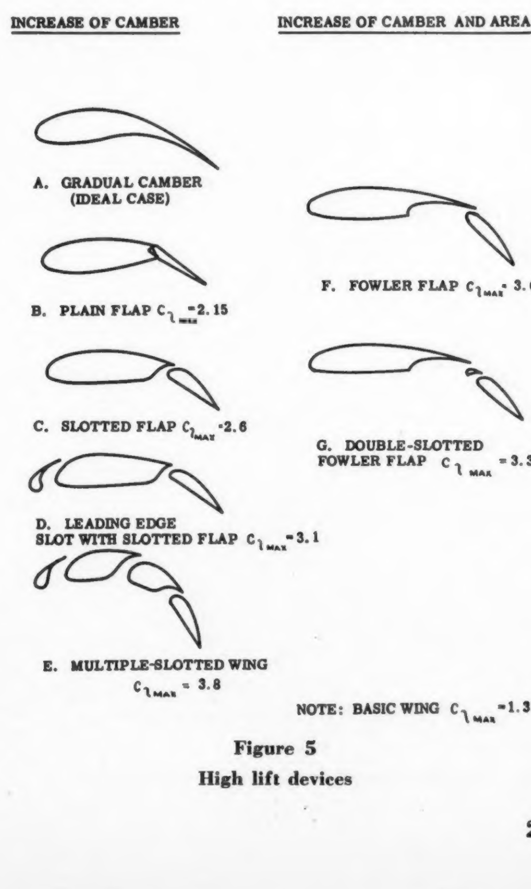


Figure 5

High lift devices

attack used for cruising and high speed, as to be impracticable today.

The flap was developed as a practical means of increasing camber at will. The split flap and the plain flap (Figure 5B) are mechanically simple but the change of upper surface curvature is so abrupt at the flap that at fairly small deflections the flow separates, thus limiting lift benefits and increasing drag. The slotted flap (Figure 5C) is more subtle in that it achieves a transfer of flow from the high pressure region below to the upper surface. The passage through the wing is a constricting one and shaped so that the air emerging on the top surface mixes smoothly with the boundary layer. This mixing energizes the flow and reduces its tendency to separate.

Thin, high-speed airfoils have fairly sharp noses, around which there is appreciable flow at high angles of attack. The effect is accentuated when flap efficiency is high. The maximum lift under these circumstances is apt to be limited by flow separation on the nose rather than the tail of the airfoil. The elementary boundary layer control slot used in the flap can be employed here; the device is the familiar leading edge slat (Figure 5D).

One could extend the use of the slot, granting weight and complication penalties, and arrive at the multiple-slotted or "venetian-blind" airfoil (Figure 5E). The currently popular double-slotted flap is a judgment of the point of overall diminishing returns when one proceeds in this direction.

We saw earlier that the takeoff and landing distances vary directly with wing loading. Obviously increase of wing area would be beneficial. The Fowler flap moves aft to increase wing area by practically the flap area, and increases camber in addition. The refinements of the slotted flap can be incorporated (Figures 5F and G).

In Figure 5 for the various flaps are given section maximum lift coefficients. The magnitudes are approximately the coefficients corresponding to an unswept wing capable of cruising at a Mach number of 0.7 and fitted with a full-span flap. For a thicker wing the values would be somewhat higher; for a thinner or a swept wing there would be a definite reduction in magnitudes. The significant thing to note is the point of diminishing returns that is reached in flap benefits. Since takeoff or landing distance varies roughly inversely as $C_{L_{max}}$, we see that a good full-span single-slotted flap, which can double $C_{L_{max}}$, can halve the ground run. Going further to the extreme, overall complication of the multiple-slotted wing, the distance corresponding to the single-slotted flap can be reduced only about 30%. Thus, it seems clear that STOL capability can be achieved in the conventional airplane only through use of impracticable wing loadings or thrust-weight ratios.

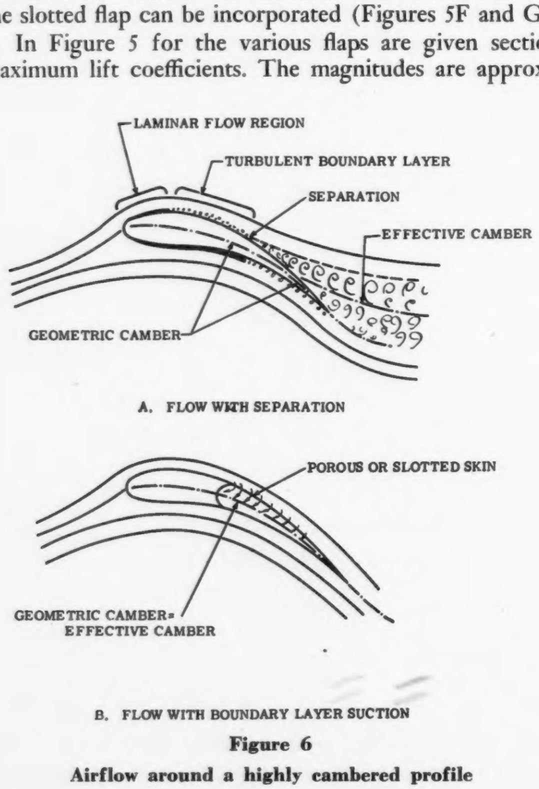


Figure 6

Airflow around a highly cambered profile

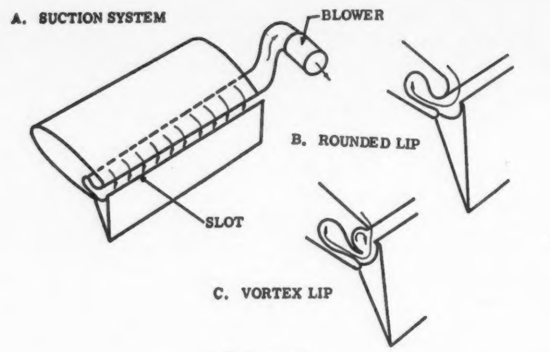


Figure 7

Boundary layer suction

Boundary Layer Control

Here we mean artificial control of the boundary layer, as distinguished from the natural control exhibited in the slotted wing and flaps above. These latter devices are limited in effectiveness by the weak pumping action available at low airspeeds and we have seen they are not capable of producing true STOL capability. Further increases in lift effectiveness can be had through artificial means, which act at strategic points either to suck away the boundary layer or to pump highly-energized air into it.

Figure 6A shows a highly cambered airfoil operating near the maximum lift condition. The boundary layer history is illustrated schematically. The separated flow area acts to reduce the bending of the airflow much as a local reduction (reflexing) of the camber would do.

Now consider the region of separated flow to be eliminated by distributed chordwise suction into the airfoil interior (Figure 6B). The flow re-attaches to the airfoil, the effective camber again corresponds closely to the profile geometry, and both lift and drag are improved.

Figure 7A shows the elements of a possible suction system. Boundary layer air is sucked from the wing through an internal duct by a blower, which exhausts elsewhere to energize a boundary layer or to obtain a jet reaction.

Large, gradual camber with area-distributed suction is a high-lift ideal. In practice, suction boundary layer control has been used almost exclusively to improve flap

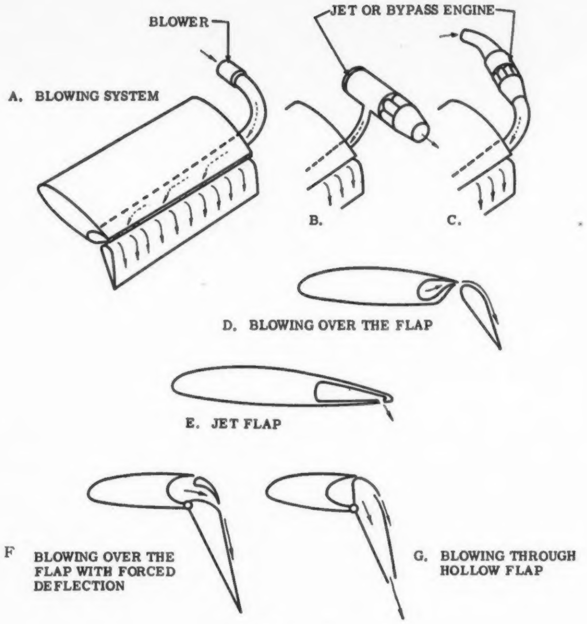


Figure 8

Boundary layer blowing

effectiveness by reducing separation. The entry into the wing of the sucked air must be shaped well and several schemes have been used (Figure 7B and C). Under these conditions, with practicable suction flow quantities, it is possible to achieve lift benefits somewhat better than for a good double-slotted flap.

By employing suction at various points on a flapped airfoil, in order to delay separation as much as possible, section $C_{L_{max}}$ values of about 4.0 have been attained; this is slightly better than for the multiple-slotted profile of Figure 5E. The limitation to the benefits is due to the low vacuum pressures required.

Boundary layer control by blowing avoids this drawback of the suction technique. Here ram air can be used to feed a blower, the output of which is exhausted strategically into the wing boundary layer (Figure 8A). Alternatively, compressed air could be bled from a turbojet or bypass engine; in the limit the entire flow of a turbine engine could be used (Figures 8B and C).

Blowing over the flap is relatively quite efficient, hence most applications are of this sort. Figure 8D shows one scheme wherein the so-called Coanda effect is utilized to keep the ejected air attached to the flap contour. $C_{L_{max}}$ values of the order of 6 are possible without unreasonable flow quantities. A recent approach is the Davidson jet flap; here high velocity air is ejected downwards from a slot near the trailing edge (Figure 8E). The jet sheet acts as a flap to deflect the general flow, as an energizer to the boundary layer in delaying separation, and also to extend the wing chord as in the Fowler flap. The lift benefits vary almost directly with ejected mass flow. Several times the flow quantity used in the Figure 8D scheme are required for a given $C_{L_{max}}$ but by use of the entire flow of an aircraft's turbine engines for a jet flap, $C_{L_{max}}$ values of the order of 12 would be possible and we would have true STOL. Further, in flight by ejecting flow directly astern we would have a propulsive wing. However, this flap would have unmanageably large pitching moments. There also appears to be at present a very small angle of attack range associated with high lift. Figures 8F and G suggest ways in which these difficulties could be reduced.

By combining suction and blowing, the total flow handled for a given degree of boundary layer control can be reduced about one-half. In the Arado system, which has been used experimentally with success, suction is applied to the inner wing and the air is ducted to the outer wing, where it is used for blowing control. The system is limited by the relative weakness of the suction feature.

Blowing and suction control can be combined in the chordwise, rather than the spanwise, sense. The blowing could be done as described above, with the suction being applied to wing regions tending toward flow separation, or with suction flow from the nose stagnation region (Figures 9A and B).

Poisson-Quinton suggested an ingenious arrangement of combined control (Figure 9C). The basis was a flapped airfoil with a broken camber line ahead of the flap. Compressed air induced a suction flow to preserve the flow across the break in the upper camber and this flow was ejected to provide boundary layer control over the flap. Lift coefficients, somewhat better than those attainable with simple blowing over the flap, have been demonstrated.

Summary Remarks on High-Lift Systems

The non-rotary wing with separate propulsive system is not a VTOL system and using the conventional flap and slat high-lift devices does not give STOL characteristics either, because of the rapidly diminishing returns achieved by a given amount of design effort as the absolute takeoff and landing distance diminishes.

The blowing type of boundary layer control is more effective than suction at higher mass flows, which are possible in combination with turbine power plants. Further, with blowing control, there is the possibility

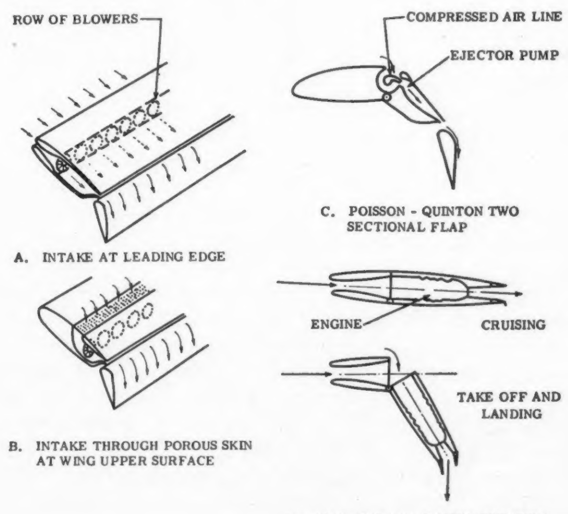


Figure 9

Chordwise suction and blowing

of designing so that the blowing system can be used as a propulsive means in forward flight. The jet flap principle could be applied toward this end.

Figure 9D shows an extension of the jet flap idea, using a series of turbojet engines distributed spanwise through the wing. A very high-lift system is created using combined suction and blowing control; STOL and perhaps eventually VTOL capability could be achieved, given enough power. In forward flight the same components provide a propulsive wing, which has good high Mach number characteristics despite its depth, since the internal flow improves the compressible aerodynamic effects of the relatively thick airfoil used.

APPLICATION OF LIFT AND THRUST PRODUCING SYSTEMS TO VTOL AND STOL AIRCRAFT

Let us now consider the application of these various ways of producing lift or thrust to the design of existing and conceivable types of VTOL and STOL aircraft. A consideration of the pros and cons of the force-producing means is apt to indicate the degree of technical merit in a given case.

Fixed-wing aircraft

Obviously the conventional airplane lacks VTOL capability. Further, studies based on the above considerations show conclusively that, for widely practicable wing and thrust loadings, a true STOL characteristic cannot be achieved using any reasonable camber-changing device. This is not to say that highly-flapped light airplanes, designed for liaison, pleasure, bush and similar operations, cannot fall into the STOL category.

Suction boundary layer control does not change the situation a great deal but, using pressure rather than suction, the attainable $C_{L_{max}}$ is worth striving for, especially with turbine engines to provide large air mass flows. Boundary layer control by blowing deserves more engineering application than it has enjoyed to date.

The jet flap promises an additional sizable increase in lift — so much so that the associated problems of longitudinal stability and control appear formidable. Sufficient modification and elaboration of the basic idea may prove the jet flap feasible, in which case it could give an airplane of respectable top speed at least greatly increased range and/or payload for given runway length, if not actually STOL at reduced useful load. The bypass engine would lend itself readily to supplying the flow quantities required for the jet flap.

Assuming the eventual goal to be attainment of higher and higher forward speed, the fixed-wing goal would appear to be some form of combined high-lift and propulsive wing (for example, Figure 9D). Here the thrust-producing and auxiliary lift means are the same — a system of turbojet, bypass or perhaps pressure jet engines. Whether an arrangement like this could be made structurally sound is a fair question, but the chordwise flow arrangement would be efficient. Incorporation of boundary layer suction to maintain laminar wing flow in high speed flight would give practically an aerodynamic ideal. Nevertheless the large flow quantities and camber change would provide very high $C_{L_{max}}$ magnitudes.

Since the flapped wing has known lift capability, given some relative airspeed, use of tractor propellers or rotors, spaced spanwise along the wing to create a relative wind for the wing, is a reasonable direction of research effort. Here the auxiliary lift device is the thrust producer so that, for lower-speed aircraft, there would be a practicable aircraft possibility.

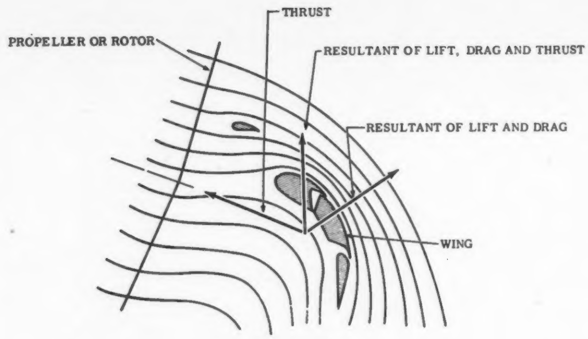


Figure 10
The principle of slipstream deflection

Considerable work has been done in this direction, especially by N.A.C.A. in the U.S.A. A promising scheme is illustrated in Figure 10, wherein a large-chord, multi-section flap is used to deflect the slipstream downward as much as 70° under favorable conditions. By vector addition of thrust, wing lift and drag, one can obtain a vertical resultant force if the system has an attitude of about 20° to the horizontal. Due to slipstream drag, the useful resultant force is at best about 90% of shaft thrust.

Granted that, by using turbine engines and large propellers affecting the entire wing span, one can generate enough lift to hover. N.A.C.A. experiments indicate that a turboprop transport of 60 lb/sq ft wing loading could hover with all engines operating to give a power loading of 4.3 lb/shaft hp. For comparison, the Convair 440 Metropolitan transport has this same wing loading but, with only 44% of the power (9.8 lb/BHP), provides one-engine-inoperative safety, although it requires for this operation a takeoff runway length of 5000 ft at sea level. However, the creation of large lifts tends to bring about large nose-down pitching moments, which would be very serious here since the horizontal tail is operating in relatively slower air. To overcome this, the thrust line can be placed below the center of gravity; an auxiliary vane placed above and ahead of the wing is effective in that it contributes lift and favorable pitching moment.

Aircraft control at very low speeds would be obtained by flap motion, propeller pitch changes and compressed air jet reaction. There is no doubt about the fact that, as VTOL flight is approached, the static and dynamic stability and control problems of the fixed-wing configuration become very serious.

Rotary-wing and associated aircraft

Autogyro and Helicopter

The autogyro, which had a free rotor for lift and a propeller for propulsion, was made practicable by Cierva with the flapping hinge; it was hardly an STOL aircraft, since it had to be taxied sufficiently for the aft-tilted rotor (Figure 12A) to attain speed by absorbing airstream energy. This aircraft type finally had vertical takeoff ability. It was possible to transmit some torque to the rotor and thus store flywheel energy in it; sudden

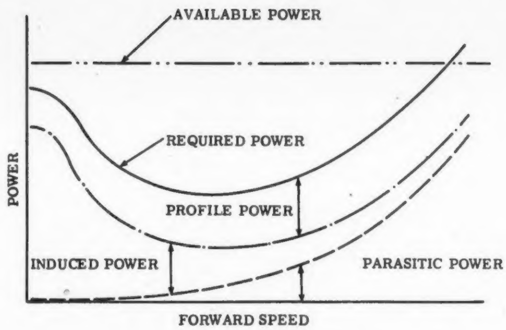


Figure 11

Typical rotary-wing aircraft power-speed diagram

increase of rotor pitch permitted a jump takeoff. Steep descent in the landing approach allowed enough rotor energy to be stored that a flared near-vertical landing was possible. By these means, and by use of cyclic pitch, it was possible to dispense with the fixed wing. Nevertheless, the jump technique and the overall inefficiency were too great obstacles.

The helicopter combines the lift and propulsive systems and gives true VTOL ability. Although the rotor system is fairly heavy and the powerplant system more powerful than for the comparable airplane, the helicopter carries a decent payload and so is doing a wonderful job where VTOL ability is necessary.

Looking at the speed potential of the type, we find very serious drawbacks. Figure 11 represents the power required and available against airspeed for a typical helicopter, with the intersection of the two curves fixing the high speed. The elements of the power required are shown. In hovering most of the power is lost in the slipstream (induced power) with the remainder lost in rotor blade profile drag. At an intermediate speed, of the order of 70-90 mph for present-day machines, the power requirement minimizes; this gives a rather low airspeed for efficient cruising. In high speed flight the parasitic losses of rotor hub, blades, rotor pylon, antitorque propeller, fuselage, landing gear, etc. (Figure 12B), cause very steep increases in power required, so that even today the rotary-wing speed record is under 200 mph.

Equally serious for the helicopter's high speed potential are the dynamic problems in the rotor system. The rotor system experiences vibratory stresses because of changes of angle of attack and relative airspeed experienced by the blade during its rotational cycle in forward flight. These stresses are so important in design that most of the rotor system is designed by fatigue considerations. Since we do not yet understand well either the phenomena or how to design properly for fatigue life, the rotor system is slow in development, heavy, expensive, subject to wear and breakage in service, and hence requires close inspection and frequent parts replacement. In a helicopter of, say, 120 mph top speed, the rotor system stresses are apt to be no more serious at maximum speed than in the worst low-speed condition (which may be transition from hovering into full forward flight, oddly enough). Designing for increased high speed in the pure helicopter assures that the power required and vibratory loads will be excessive, and finally that excessive vibration, loss of control or blade flapping instability will be brought on by alternative compressibility effects on advancing blade and stall effects on retreating blade.

Then, since the pure helicopter is inefficient at higher forward speeds and comparatively heavy, it is best suited to low-speed, short-haul work. Because of this inherent characteristic, it gains a great deal by substitution of light turbine powerplants for the piston engine, despite higher specific fuelflows.

Flying Platform and Ducted Rotor

An increased lifting efficiency is made possible by a shroud surrounding the rotor, as pointed out previously. The Hiller flying platform applies this principle, shown schematically in Figure 12C. In the Hiller machine, contra-rotating, coaxial, multi-bladed fans are submerged within a bellmouthed duct. The short blades have a fixed pitch. This is possible because the operator shifts his weight to change aircraft trim in place of cyclic pitch change; since fan inertia is low, rpm changes can be made rapidly enough to substitute for the collective pitch control of thrust output. The duct acts to reduce the oscillatory character of the blade flow in forward flight. Dynamic stability is present due to rotor damping. While the aircraft may be unsatisfactory from the standpoint of engine failure and other aspects, it is a very interesting exploratory effort.

Projecting the flying platform into a larger, multi-engined machine, one might arrive at the aircraft of Figure 12D, which could be used conceivably for army reconnaissance and general utility work. Trim changes would be accomplished here by vanes making up the lower periphery of the shroud. If the simplicity of the flying platform could be maintained, this could be an attractive aircraft type.

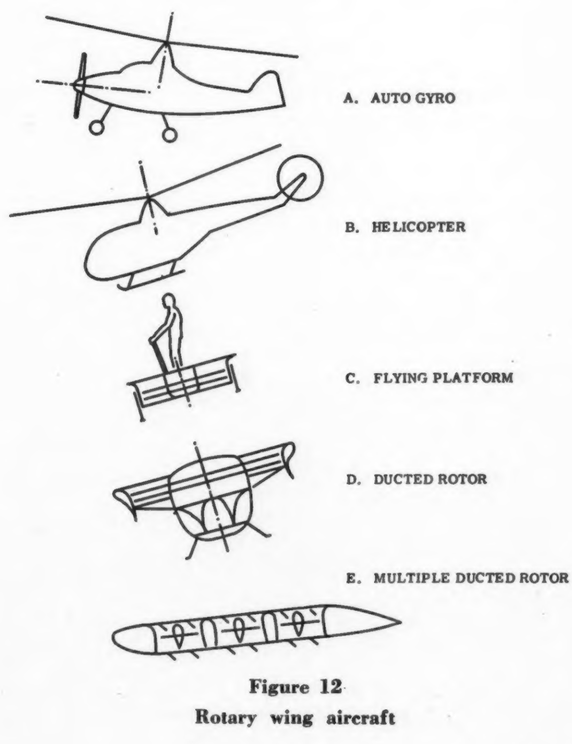


Figure 12

Rotary wing aircraft

Multiple Ducted Rotor aircraft

Admittedly, the aircraft of Figure 12D is limited to slow speeds because of its poor aerodynamic shape. One could encase the rotor within a streamline body to remedy this, if desired. Lippisch in the U.S.A. has apparently done this with a series of model rotors, as in Figure 12E. By fan rpm changes and vane control of entrance and exit rotor flow, it would be possible to obtain lift, propulsion and control. At the speeds possible with disks or other slender shapes, it would perhaps be better to use separate engines for propulsion (for example, pressure jets supplied with air from compressors driven alternatively by the lift engines). The body shape could provide the necessary lift.

Unloaded-Rotor Convertiplane

The pure helicopter is limited in speed potential, even given unlimited power, because of dynamic problems of the rotor system. By reducing the rotor pitch, the blades would flap less in response to the cyclic changes in relative airspeed and the vibration and stress difficulties could be delayed until higher speeds. But reducing the rotor pitch requires auxiliary lift and propulsive means. The McDonnell XV-1 convertiplane (Figure 13) is a helicopter, which in forward flight transfers the rotor lift burden onto a small wing and the propulsive function to a pusher propeller. In the short-duration helicopter regime the rotor is pressure-jet-driven, the air being supplied by an engine-driven compressor through the hub and blade ducts to the tip jets. In airplane flight (as in the Figure) the rotor autorotates at reduced rpm and the engine drives the propeller. The pressure jet is more economical of fuel than the ramjet would be and penalizes rotor autorotative performance less.

This research machine has demonstrated its principle satisfactorily. Numerous "conversions" to airplane flight have been made and the rotor has behaved well at speeds slightly in excess of 200 mph. The test article is unavoidably heavy, complex and of excessive drag. It may be that the speed advantage over the helicopter is not worth the price, but the unloaded rotor principle perhaps deserves the fair test of being applied to an aircraft of larger size.

In view of the dynamic troubles that beset any rotor eventually in the speed range, thought has been given to stopping the rotor in forward flight. Some years ago, Herrick in the U.S.A. used the stopped rotor as the upper wing of a biplane cellule and recently Sikorsky has done some work toward stopping the rotor and

Figure 13
McDonnell XVI convertiplane

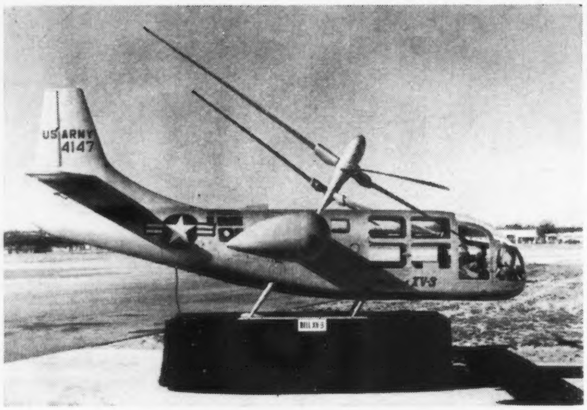


Figure 14
Bell XV-3 convertiplane

retracting it into the fuselage. There are serious aircraft control, rotor dynamic and other problems associated with rotor stopping and starting, and the higher the forward speed goal, the more grave these problems become.

Tiltable Thrust Convertiplanes

Another way of eliminating the rotor in forward flight is to convert it into a propeller by tilting its axis. The Bell XV-3 convertiplane (Figure 14) has rotor-propellers interconnected with a shaft driven by an engine in the fuselage. The disk loading is low enough to permit safe autorotative landings, so as propellers the disks are lightly loaded. Compromises were necessary in the design of the rotor-propellers for both regimes of flight. There are a number of mechanical problems, for example two-speed gearing, in the drive and rotor tilting mechanisms. The dynamics must be handled carefully because of the flexibility of the rotor on its slender shaft at the tip of the wing. The test vehicle is flying as a helicopter and probably will "convert" satisfactorily before long.

The speed potential of this configuration is expanded greatly when the rotor is replaced by the family of rotary thrust-producing systems — ducted fan, bypass engine and turbojet (Figures 15B through D). The economic choice of propulsion unit would depend upon the speed requirement of the particular application. A final step would be to the turbojet propulsive wing of Figure 15D. The turbojet applications would achieve the VTOL goal in practicable aircraft only at the expense of large amounts of installed power and very high fuelflow rates per unit hovering time. A primitive turbojet VTOL aircraft of this type has been successfully flown by Bell Aircraft Corporation. Except for the rotor-propeller type with low disk loading, this class of aircraft would require multiplicity of engines to avoid total power failure. Auxiliary jets would be used to provide control in hovering.

A rather different VTOL aircraft, but still of the tiltable thrust category, is the disk with radial jet flow directed downward at the periphery. The vehicle hovers through the combined action of the jet thrust and the lift-producing induced flow over the disk. Forward flight is achieved by directing horizontally the radial jet flow

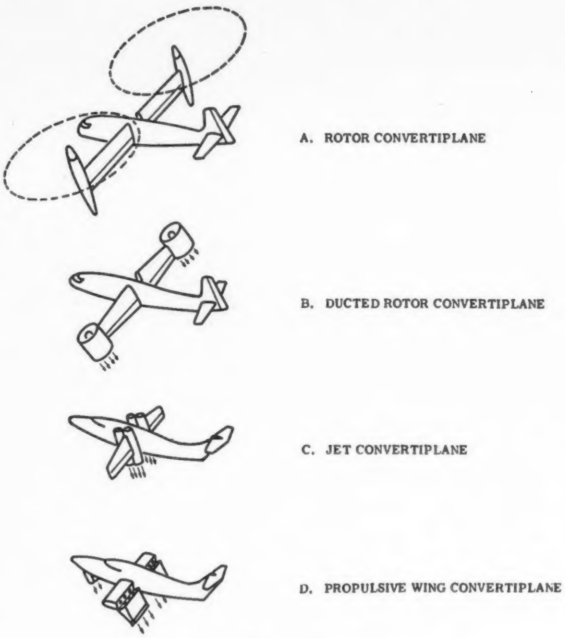


Figure 15

Tiltable thrust aircraft — convertiplanes (shown in conversion stage)

over a small sector of the disk. Trim changes can be made by small changes in jet direction. Since in high speed flight the disk can provide lift, most of the radial jet units can be shut down. This ingenious arrangement has excellent high speed possibilities.

Tiltable aircraft

The vehicles considered maintain a more or less fixed attitude during all regimes of normal flight. While this is convenient to the human occupants, let us consider the family of tiltable VTOL aircraft wherein the lift means becomes the thrust producer through the tilting of the entire craft as it begins forward flight. In the first category are the winged vehicles (Figure 16A), with the wing providing the forward-flight lift. Turboprop power was used in the Convair and Lockheed experimental airplanes; the turbojet is used in the Ryan machine, which is ready for flight; the rocket has been used in numerous ground-to-air missiles. It is apparent that the lift producing means here is so inefficient at zero speed that payload and hovering time are very small indeed.

The idea of using a ducted fan for hovering lift, and of using an extended-chord shroud as a wing in forward flight, is incorporated in the coleopter of Zborowski (Figure 16B). The power required to hover is reduced well below that necessary in the winged turboprop VTOL craft above. Experiments show that the ring-shaped wing is reasonably efficient. The induced drag is about half that of the straight wing of the same planform area; the profile drag is of course about π times that of the reference wing. Since the wing has excellent structural geometry, it can be made quite thin, hence the high Mach number characteristics are promising. For very high speeds, the space between the shroud and central body would be a ramjet, with an afterburning turbojet or bypass engine in the central body for VTOL

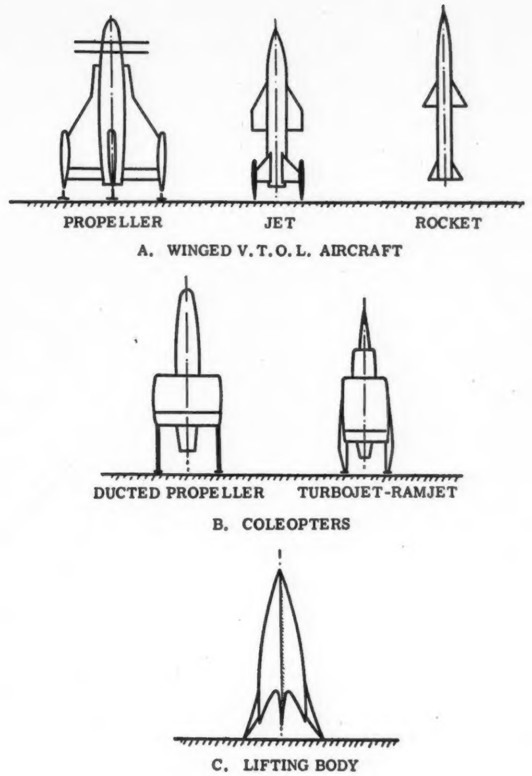


Figure 16

Tiltable aircraft

and lower speed operation. Several promising coleopter projects are in progress in France and elsewhere.

We see the tendency, as speeds increase, for the propulsive system to dominate the aircraft. This tendency would be accentuated in high speed VTOL vehicles. The wing tends to become a minor appendage. Finally, the wing disappears into the body and influences it only to the extent of giving body contours suitable to generation of lift at extreme speeds (Figure 16C). Beyond this is the purely ballistic body, utilizing thrust and inertia only to fly its trajectory at tremendous speeds beyond the atmosphere.

CONCLUSIONS

We must now regard our study of aircraft types from the ultimate point of view of the operator. By examining

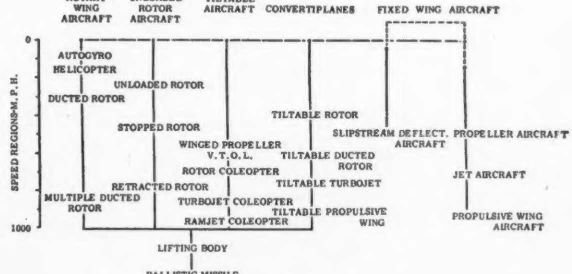


Figure 17

Family relationship of VTOL and STOL aircraft

the various types as to their ability to incorporate desirable range-load-speed combinations, we can draw some conclusions (Figure 17).

For cruising speeds between zero and those attainable by propeller craft (say, 500 mph) and for short range, future prospects for high percentage payload in VTOL aircraft are probably brightest for the pressure jet helicopter — for example, as a flying crane. Its weight empty can be quite low, its fuel economy better than the ramjet, and the helicopter's maintenance problems appreciably reduced by eliminating the rotor transmission system. It has, of course, the basic limited speed capability of the helicopter. However, if the mission required low noise level and/or prolonged hovering, the turbine-powered helicopter would be a better choice. Multi-engine aircraft employing the ducted fan will probably have application in this area, especially if the transmission problem can be avoided. The tiltable thrust rotor convertiplane would also be applicable, if one could sacrifice payload to gain cruising speed. Or, if it were possible to admit STOL as well as VTOL aircraft, the slipstream deflection airplane would provide good cruising speeds with payloads greater than the convertiplane, although less than the jet helicopter.

Retaining low to moderate speeds as above, but requiring longer range (say, 1,000 miles or better), we find the best VTOL possibilities with high percentage payload in the large turbine-powered helicopter and in the tiltable-thrust rotor convertiplane. The choice between the two would be on the basis of payload versus cruising speed and complication. In the STOL category, the slipstream-deflection aircraft would be able to provide longer range with good propeller-airplane efficiency.

We now arbitrarily stipulate moderate to high cruising speeds, say between a Mach number of 0.7 (or 500 mph) and Mach number of 1.5 to 2.0, where aerothermal effects become dominant. If we accept short range, as in an interceptor, the turbojet tiltable aircraft and the coleopter with ducted fan or turbo-ramjet engines are obvious candidates for VTOL development. The tiltable thrust disk aircraft with radial jet flow is an inviting prospect here. By accepting STOL characteristics, we could add the aircraft with high-lift propulsive wing (principle of Figure 9D) to the possibilities; actually with reduced load this configuration could be the VTOL tiltable thrust convertiplane of Figure 15D. With a requirement of only several hours duration, which infers several thousand miles range, there is immediately the need for shapes giving low drag per unit volume because of the fuel required. It may be that the best VTOL type here would be the disk aircraft mentioned above, for it promises the required fuel space and relatively good lifting efficiency. In the STOL category the possibility of the high-lift propulsive wing could be examined; the optimum solution might be a high subsonic design with flow laminarization by suction boundary layer control provided by the engine intakes.

Moving again arbitrarily up the speed scale to the Mach range beyond 2.0, we in effect eliminate the short-range vehicle, for even a short duration results in a long range. Further, aircraft with air-breathing engines would experience such serious aerothermal heating that the allowable shapes would be very simple, e.g. the disk. Actually, to avoid artificial surface cooling at the very high speeds, it would be necessary to elongate the disk into a "planing" or "lifting" type of body. These very high speed vehicles will be slender envelopes around a tiny payload and huge propulsive and fuel systems. They will be the ultimate aircraft types, for the next step in speed forces us beyond the atmosphere with rocket-propelled ballistic shapes, to which the term "aircraft" does not apply.

While it is impossible to be quantitative on the broad subject of VTOL and STOL after so brief an examination, one intuitively feels that VTOL and STOL capability will be so expensive in range-load characteristics as to preclude it, except when required by the nature of the operation. Two notable exceptions to this generality are:

(*a*) in quite short range, low speed operation, the helicopter, especially the pressure jet type, has real advantage, and

(*b*) at very high speeds within the atmosphere, the aircraft shapes required are such as to lend themselves to, or to require, VTOL characteristics.

Even though designing for VTOL or STOL capability may not be advisable for most aircraft, increased application of VTOL and STOL techniques should not be overlooked as a means of designing better aircraft.

SOARING IN CANADA†

by C. B. Jeffery

Gatineau Gliding Club Inc.

SUMMARY

Soaring activities in Canada at the present time are outlined. Most soaring has been done in the east, but the longest flights have been made in Saskatchewan. The best sites are perhaps still to be explored. The lack of hill sites has caused the extinction of the primary glider and the use of aero-towing and two-place training. Sailplanes in use include two-place designs of wartime construction and imported and native designs of medium high performance. The clubs own and operate most equipment; private ownership and cross-country soaring are increasing. The functions of the Soaring Association of Canada are outlined. Canadian records have increased from small values in the 1940's to about half the present world records.

INTRODUCTION

"The powered aircraft provides the quickest, least tiring and most satisfactory way to deliver a business man to his board, or an atom bomb to Hiroshima. Its functions may quickest be summed up in two words: death and dividends . . .

"But I don't leap into my sailplane when I want to go anywhere, or when I want to kill someone or to stop him killing me. I leap into my sailplane when I want to fly."

—Philip Wills: *"On Being a Bird"*

It is often asked, "what is the use of gliding?" Wills, Shenstone and others have set down a number of ideas on this, all reducible to the fact that, like skiing and sailing, it is of very little use at all. This is really said to emphasize that gliding is primarily a sport. As in the case of sailing, there is a considerable training value in gliding, very little exploited as yet in Canada, and there have been dramatic military applications of sailplanes and sailplane training. These practical values are not purchased by anyone; anyone engaged in soaring, instructing, or learning the art, does so for its own sake.

SITES AND WEATHER

Canada offers the soaring pilot many types of soaring terrain and meteorology; in fact there is only one type of site, the hill site, of which there is no good, accessible example known.

The mountain ranges and valleys of British Columbia undoubtedly have a great potential for soaring in thermals, hill lift and mountain waves. A little soaring has been done in Vancouver, but apparently the immediate coast suffers from the usual damping effect of the sea breeze. Considerable thermal activity has been observed over the North Shore mountains, unfortunately not from sailplanes however. The Chilliwack area has been the site of some gliding but experience suggests that the whole centre of the Fraser Valley is subject to subsidence; any thermal activity over the Cascade range has not been successfully explored yet in Canada. Inland, the warm Okanagan Valley also has unexplored but promising characteristics.

The Chinooks are almost surely associated, at least occasionally, with powerful wave systems similar to those in which the world's altitude records have been set, in California and New Zealand. Here again, we can only report the most preliminary and rare exploration by sailplane, with failure to contact wave lift.

Some fine altitude flights and short cross-country flights have been carried out in the Calgary region; the Edmonton area will surely prove far better though, when a pilot and sailplane occur together there for the first time. The Edmonton skies seem to be filled with a most regular pattern of cumulus for the majority of July days.

Saskatchewan is the site of the two longest flights so far made in Canada. These were made by pilots visiting the prairies on excursions from Ontario in 1953 and 1955. In spite of the gratifying results, soaring conditions on the prairies were disappointing to these pilots in that there were few soaring days and thermal activity was weaker and more subject to disruption by strong wind than had been expected. In Manitoba, some good flights from Winnipeg by R. Noonan have been curtailed by the U.S. border or the termination of thermal activity. If good conditions on the prairies actually exist, they will no doubt be exploited by the local pilots before long.

The Ottawa valley and the isthmus of Ontario have so far been the scenes of most of Canada's soaring. The 300 mile run from Killaloe to Megantic is a little rough at each end but it is dotted with 15 airports and, for the most part, carpeted with level farmland. It also has good soaring conditions on at least one summer day in three. Soaring conditions are considered excellent in the Ottawa valley on a day when cloud base is at 6,000 ft and there are thermals giving an 8 fps rate of climb. By contrast, in Texas or California, cumulus cloud may form on top of thermals at 18,000 ft.

The notable exception to our complement of sites is a natural, accessible soaring ridge. The gliding sites of one's imagination are perhaps based on the fine

†Received 8th May, 1956.

European hill sites such as the Wasserkuppe and Dunstable, where hangar and gliders are kept on top of the hill and gliders can be launched into the updraft over the ridge by means of a large slingshot. The lack of such sites in Canada has made a considerable difference in the appearance of our gliding activities.

SOARING AND FLYING TRAINING

On our flat sites, we can still manage training without resorting to propellers and power pilots, by using winches or automobiles for launching. For satisfactory soaring, however, 600 or 800 ft launches by ground equipment are inadequate. Most Canadian clubs have, therefore, purchased Tiger Moths or other tug aircraft and have fairly rapidly thereafter discontinued winch and auto-towing. The conversion to aero-towing proceeded largely between 1947 and 1950, the Queens Gliding Club making the first purchase, followed by the Montreal Soaring Council, the Gatineau Gliding Club and several others. The use of aero-towing necessitates instruction in two-place gliders. The need for two-place equipment has been filled by war surplus American types described later. The use of dual instruction has, of course, resulted in a much higher standard of training and proficiency.

About two-thirds of the gliding activity is instructional, including some soaring. The instruction is all on a voluntary basis, but there has been no shortage of instructors so far, as the work of instruction and the flying time provide enough compensation. A quarter of the flying is local soaring and the remaining small fraction is cross-country soaring. It seems that heading away from the field in a sailplane is not a small step for an amateur pilot and only a few have so far tried cross-country soaring; one only has to sample cross-country soaring to become addicted to it though and, as with other forms of soaring, there has been a considerable increase in cross-country mileage in 1954 and 1955 (Table 1). There is little doubt that many more pilots will enjoy this form of the sport in the coming seasons.

TABLE 1

Year	1949	1950	1951	1952	1953	1954	1955
Cross-country Mileage at National Meets	60	0	600+	550	600+	1300+	1200+

The annual number of hours, clubs, pilots and gliders according to Soaring Association statistics are shown in Figure 1.

GLIDERS AND SAILPLANES

Primary gliders, with their open frame fuselage structures, numerous bracing wires and angular forms, no longer grace the Canadian skies — or rather the extreme lower atmospheric layers they were capable of reaching (Figure 2). In the 1940's, about a dozen primaries were built and flown. The latest, a design by Czerwinski built in Toronto in 1947, is believed to have been written off last year after a long period of disuse. The disappearance of the primary is not a matter for great regret, but the experience of sitting on a breezy, semi-controllable two-by-four, several hundred feet off the ground, gave a thrill not easily forgotten.

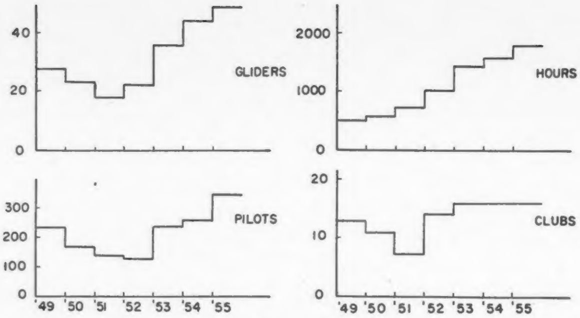
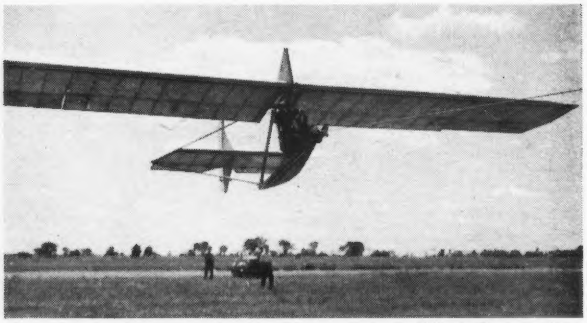


Figure 1
Annual statistics



Wally Hinman Photo

Figure 2
Dagling taking off

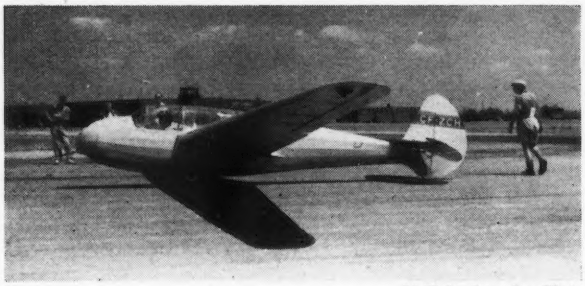
The primaries have been replaced for training by enclosed two-place sailplanes of relatively clean design. These sailplanes were obtained from the U.S. war surplus market at a small fraction of the original cost and have in themselves enabled progress to be made at an otherwise impossible rate. The characteristics of the three most important types are given in Table 2. The Laister-Kaufmann TG-4A appears in Figure 3.

TABLE 2
Training Gliders.

	Laister-Kaufmann TG-4A	Schweizer TG-3A	Pratt Read LNE-1
Span Feet	50	54	54.5
Aspect Ratio	15	12.3	13
Equipped Wt Lb	511	820	770
Gross Wt Lb	911	1220	1150
Type	Tandem	Tandem	Side By Side
Min Sink Speed FPS	3.5	3.7	
Max Glide Ratio	22	21	
No in Canada	8	4	4

Five German intermediate sailplanes imported at the end of the war, once reconditioned, have given many hours of service. These are low-speed, pre-war, single place designs Grunau Baby II and Mü-13. One of the 4 Grunaus has been irretrievably written off.

Post-war sailplanes of foreign construction now being used in Canada include the Olympia from Britain (Ottawa) (Figure 4); Schweizer 1-23 and 1-26, metal, single



McNulty-Laundry Photo

Figure 3
Laister-Kaufmann TG-4A

Wally Hinman Photo

Figure 4
Gatineau Gliding Club Olympia

place American designs (Montreal, Toronto); Schweizer utility 1-19 and 2-22, tube and fabric single and dual trainers (various locations); and German two-place sailplanes, Doppelraab and Bergfalke (Toronto).

Recently, amateur construction of gliders has increased. The most ambitious project so far completed has been the construction of four Fauvel A.V.36 tailless aircraft at Calgary by R.C.A.F. officers Riddell, Brown, Murray, and Russell. Due to transfers, these sailplanes are now spread between Comox and Ottawa. Three more Fauvels have been partly completed as the joint project of the Buckingham, Montreal and Sherbrooke clubs. Five other Fauvel construction files have been sold in Canada.

Next to the Fauvel in popularity for home construction is the Schweizer 1-26, a small metal sailplane sold in kit form. Two are under construction in Montreal and one in Toronto. Incidentally, the Schweizer factory has recently started work on the second run of fifty 1-26's. A Schweizer 1-23 and a Grunau Baby are the products of individual efforts on the prairies.

Design in Canada has been almost entirely the province of Polish-born engineers. W. Czerwinski, with collaborators, has produced six designs since coming to Canada. Four have been built and flown: the Wren, a primary, two utilities, Robin and Sparrow, and the intermediate sailplane Loudon UTG-1 (Figure 5). The Harbinger, an advanced two-place, co-designed with B. S. Shenstone, is under construction in London. A very advanced single-place machine is in design at the University of Toronto, but no sponsor for its construction is in sight at present.

An interesting swept-wing tailless, designed by Brochocki, Bodek and Kasprzyk, is nearing completion in Montreal.

The latest in a long series of gliders, built by Norman Bruce of Calgary, is a refined version of the Grunau Baby, known as the Zephyr.

THE CLUBS

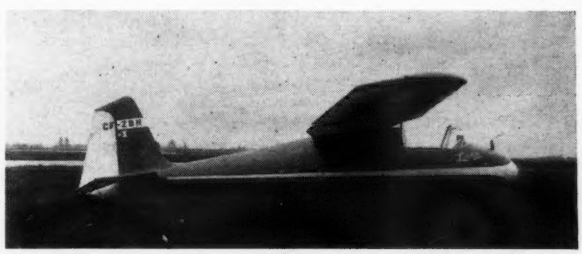
Until recently the gliding clubs have owned nearly all gliding equipment. The clubs vary in size from three or four members to 60 or 80 members, as in Montreal, Toronto and Red Deer. The Montreal Soaring Council is an association of clubs and individual members. The group at Brantford, now known as the Southern Ontario Soaring Association, includes the Toronto Gliding Club and other clubs and individuals.

Most clubs have small fees and rates, and hence small revenues. If they are short of funds, they are traditionally long on improvisation and voluntary work. Almost without exception, each club has a nuclear group of members, which may in fact include all members, who are willing to spend much of their spare time in construction, repair, servicing, accounting and other work, in order that the club may continue to operate at moderate rates or, in fact, to operate at all.

The Southern Ontario Soaring Association should be specially mentioned as it is the largest and most active group in Canada at present. The Toronto Gliding Club pooled facilities at Brantford with clubs from Kitchener, London and Hamilton; the group now boasts twelve sailplanes under its wing, six privately and six club-owned. A harmonious working agreement with the Brant-Norfolk Flying Club has been worked out. All gliding club members join the flying club and the gliding club rents a block of hangar space from the club. Thus all gliding club members have legitimate use of the facilities of the flying club and the latter benefits from the increased level of activity at the airport.

No one should conclude from the above paragraph that the Toronto Gliding Club is the best in Canada. The author will be the last to sign that credit over from the Gatineau Gliding Club. The Gatineau Club operates in the Ottawa Valley and is blessed with a fine soaring region; as a result, the Club holds many Canadian records and half the higher soaring awards. The Club brought the first high-performance sailplane into Canada and early converted to aero-towing and dual instruction. Gatineau Club members initiated the Soaring Association of Canada, whose purposes are described later.

The clubs and the sport of gliding are not encouraged or subsidized by the Government except in one substantial matter: the provision of hangarage and airport use to one or two clubs. The Gatineau Gliding Club



McNulty-Laundry Photo

Figure 5
Loudon UTG-1

in Ottawa is a beneficiary of this arrangement (for years of its early life, it was sheltered in handmade hangars on a farm field).

The willingness to work for their flying displayed by the clubs would, in fact, guarantee a manifold return on any money invested by endowment or subsidy. A fund which enabled high school students to take part in gliding at slight cost, and which compensated the clubs for their voluntary effort in training pilots, would almost certainly give a higher return in air-mindedness per dollar than any other system one might think of. If the fund relieved the cost of cross-country flying, a high standard of basic piloting skill could be cheaply developed.

A list of the active clubs and their facilities is shown in Table 3.

TABLE 3
Clubs and Facilities, 1955

Club	Gliders	Tug Aircraft	Members
Quebec Soaring Club	1 + 1		7
Sherbrooke G.C.	2 − 2	1 + Winch	
R.C.A.F. G.C. (Three Rivers)	2		
Montreal Soaring Council: McGill G.C., Canadair S.C.	5	1	
Buckingham G.C.	3	1 + 1	11
Gatineau G.C. (Ottawa)	4	1	36
Kingston G.C.	1 + 2	1	16
Brantford Group: Toronto G.C., Hamilton G.C., London S.C.	11 − 1	2	(75)
Club Harmonie (Toronto)	2	(Winch)	(50)
Regina G. & S.C.	3 + 1	1	45
Calgary Cunim G.C.	3	(Winch)	
Red Deer Cunim G.C.	(3)	1 + Auto	
Red Deer Soaring Assn.	1	(Auto)	9
R.C.A.F. Fauvel Group	3		3
Soaring Club of B.C.	1		5

NOTE: Minus = Sold or U/S.
Plus = Held but not flown.
Brackets = Estimated from 1954 data.

PRIVATE OWNERSHIP

Over the years only two or three people in Canada have owned their own gliders and sailplanes. In the last year or two though, there has been a marked increase in the number of individual and small-group ownerships. The stimulus seems to be the desire for cross-country soaring, independent of a waiting list for club sailplanes. This desire, for which the pleasure of soaring cross-country is a sufficient explanation, has undoubtedly been increased considerably by the competitive spirit that has grown from the annual national meets. It is clear that to be competitive one must have access to a sailplane throughout the meet.

The privately owned sailplanes include amateur-built Fauvel AV 36's, Schweizer 1-26 and 1-23's purchased complete or in kit-form, and two-place Laister-Kaufmann sailplanes, usually considerably cleaned up. About 10 of the 49 air-worthy gliders are privately owned.

SOARING ASSOCIATION OF CANADA

The national gliding organization, the Soaring Association of Canada, has been mentioned several times. It arose in 1944 from the need for a responsible body to represent glider pilots' interests to the Government, for a means of dissemination of news and information, and for a representative of the Federation Aeronautique International to issue soaring awards and homologate records. The S.A.C. has developed useful working relations in technical and regulatory matters with the Department of Transport, and has received considerable cooperation and freedom of action from the Department. Unfortunately, personnel licensing slipped from the S.A.C. to the hands of the D.O.T., as did aircraft approval, but with regard to the latter, there is promise of a reduction of red tape through the new light aircraft regulations.

Through the good offices of the Soaring Association of Canada, some fine trophies have been generously provided by Canadian companies for national soaring accomplishment. The British Aviation Insurance Company in 1947 provided a trophy of unique design for the best annual flight. The Shell Oil Company provided a silver bowl for the National Meet Championship, and Canadair Limited the National Championship trophy. Berkely Roden provided the Club Trophy for the club making best use of its facilities and, along with the trophy, the subject for a great deal of debate over the rules for awarding it. Jack Ames built and contributed a fine trophy for the best flight by a married person, known as the Ball and Chain trophy.

Two continuing and major functions of the S.A.C. are the publication of "Free Flight", a lively bi-monthly, edited at present by the prodigious efforts of Pete Stickland, and the organization of the annual meets. The first meets were not competitive, but were very good opportunities for trading glider experience, giving concentrated training, and for standardizing instruction and operating methods. These meets were pleasant informal affairs in distinct contrast to the high-pressure competition of the U.S. nationals. It is hoped that the training and joy-riding will not be completely overwhelmed by the competition in the future, so that the younger pilots and visitors can still enjoy the meets. That the competition is growing in importance is seen by the fact that twenty-five pilots made scoring flights in 1955, out of a probable 80 to 100 pilots at the meets. Jack Ames was the winner by a substantial margin for the second successive year.

In order to include more pilots there were three sectional meets in 1954 and 1955, one on the prairies and two shared by Ontario and Quebec. This has the advantage of a larger total competition but the two eastern meets tend to decrease to very local affairs.

CANADIAN PERFORMANCE

The first cross-country flight in Canada was a ten-mile flight from Oshawa to Bowmanville by Jack Ames in 1947. Distances rose steadily in the next two years and, in 1950, the century mark was broken by Frank

Brame flying 118 miles from Oshawa to Kingston. In 1951 Albie Pow raised the mark to 137 miles. The next increase was a result of Pow's trip to the prairies in 1953. His spectacular flight of 256 miles from Swift Current to Ray, N.D., set a record which still stands.

John Dure's duration record of 8 hrs 4 min set over the Gatineau Hills in 1949 still stands. Frank Brame's altitude record of 16,475 ft was set in California in 1955; maximum height reached in Canada so far is 14,700 ft.

Table 4 indicates that our records are of the order of half the world records.

TABLE 4
Soaring Records.

Class	Canada	World
Free Distance, Miles	256	535 (U.S.)
Distance to Goal, Miles	196	395 (U.S.S.R.)
Goal & Return, Miles	120	311 (U.S.)
Absolute Altitude, Feet	16475	44255 (U.S.)
Gain of Altitude, Feet	12615	34426 (U.S.)
Duration, Hours	8:04	56:15 (Fr.)
Speed, 100 Km Triangle, MPH	—	52 (U.S.)

We hope and believe that all these marks will shortly be exceeded. The limits of performance under Canada's weather conditions have certainly not been reached yet.

Maximum distance, duration and altitude achievements are inherently interesting and worthwhile but in the end, given a good glider and a good pilot, they are limited by external parameters — the number of hours of thermal activity during the day, the maximum height of vertical currents, or the duration of wind against a ridge. For this reason new categories are entering world and national competition. They involve racing. Speed to a fixed goal, or around a triangular course, is now being recognized as a better measure of the excellence of sailplane and pilot, than a good performance in isolation and limited externally.

The immediate need in Canadian competition is to get more people heading away from the airport. To this end, duration and altitude points will be eliminated from the national meet scoring this year, leaving all scoring on the basis of distance, with goal bonuses. In all likelihood, racing will be instituted within a year or two.

THE WORLD CHAMPIONSHIPS

In 1952 and 1954 Canadian teams entered the World Championships in Spain and England. These are undoubtedly the ultimate test of skill and include the best pilots, whether amateur or professional, from the two dozen countries represented. We did not have the least scores, though we were too close to them for comfort. This year, as in other years, Canadians will be able to fly in the contest only through the generosity of their hosts, in this case, France, in providing machines and retrieving equipment, and through industrial and private sponsors defraying the cost of the trip. The team entering this year's Internationals is the strongest yet entered and we have every hope that they will rank well up in the final scoring.

ACKNOWLEDGEMENTS

The assistance of Mr. F. A. Woodward in providing statistics, the suppliers of the photographs and of Mrs. F. A. Mason for kindly typing the manuscript is acknowledged with thanks.

BIBLIOGRAPHY

Shenstone, B. S. — *Two-seat Sailplanes*, AIRCRAFT ENGINEERING, JANUARY, 1953.

Shenstone, B. S. — *Early Days of Gliding in Canada*, S.A.C. YEARBOOK 1948-49.

Yearbook 1948-49, SOARING ASSOCIATION OF CANADA.

Wills, P. A. — *On Being a Bird*, MAX PARRISH, 1953.

Free Flight, SOARING ASSOCIATION OF CANADA.

Soaring, SOARING SOCIETY OF AMERICA.

MACHINING APPROACH TO AIRCRAFT PRODUCTION†

by H. F. Young*

Avro Aircraft Limited

In this paper on the machining approach to aircraft production, I propose to present some of the problems encountered on our latest program and the action taken to prepare ourselves for this relatively new type of manufacturing.

MATERIALS

Very early in the design stages, our Engineers determined that integrally stiffened skins and completely machined structural members were necessary to meet the design requirements. From this overall requirement, the first essential to be settled was the choice of materials. We decided to use the experience gained in the United Kingdom and the United States and machine from rolled plate and solid billets.

In reviewing some of our exceptional problems in these fields, I propose to disregard conventional materials, such as extrusions, castings and bar stock, that we have used on previous programs and will continue to use.

Stretcher stress relieved plate

We were advised by companies using heavy plate that this material should be stretcher stress relieved to minimize distortion during machining. Figure 1 shows the advantages of using material in this condition. The skin on the left-hand side was made from stretcher stress relieved plate and has no appreciable bow, while the skin on the right-hand side was made from standard rolled stock; the advantages of stress relieving are very apparent. The degree of stretch needed is illustrated in Figure 2. To obtain the maximum flatness of plate, a stretch of 0.5% is sufficient but, to stress relieve the plate, 2.0% is required to provide a permanent set.

The size of stretcher level plate available on the commercial market at the present time is limited to the capacity of the machine shown in Figure 3, which has a maximum pull of 6,000,000 lb and is capable of stretching a cross-sectional area of 140 sq in. Though not clearly shown in this figure, the hyrdraulic jaws will handle a 3″ thick plate.

It is understood that the suppliers of plate are investigating the possibility of doubling the cross-sectional area and thickness I have quoted in the very near future.

†Paper read at the Annual General Meeting of the C.A.I. in Montreal on the 3rd May, 1956.

*Chief Production Engineer

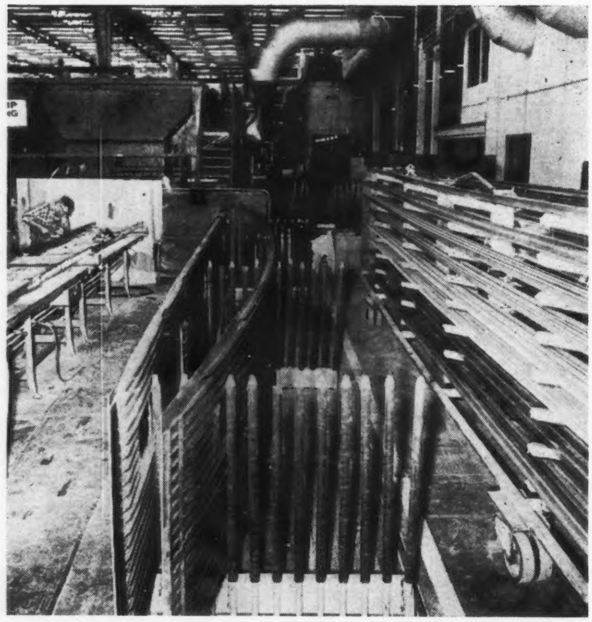


Figure 1

Comparison of skins made from stretcher stress relieved plate, left, and rolled stock, right

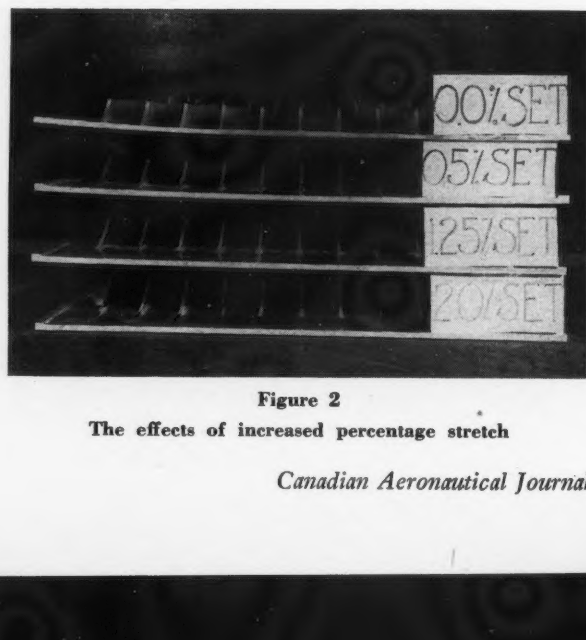


Figure 2

The effects of increased percentage stretch

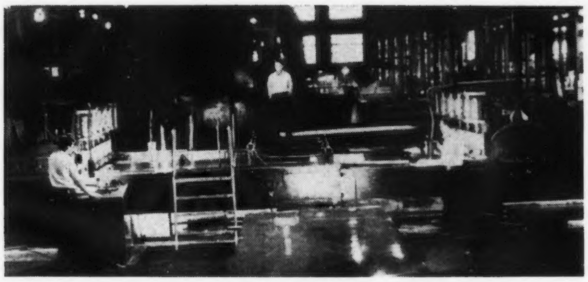


Figure 3
Three thousand ton stretching machine

Inclusions—Ultra sonic testing

To overcome the disadvantages encountered with commercial specifications for rolled 75S plate, our own specification was compiled for the ultra sonic quality requirement. In this specification, the limitation on inclusion content is laid down. The majority of inclusions are usually located within the plate and not apparent as surface imperfections, so it is important that the location and size of such imperfections are known before machining is started. To obtain this information, ultra sonic reflectorscopes are required, as shown in Figure 4. We decided that provision of such equipment by Avro for 100% inspection was unnecessary and that this problem could be handled by the supplier, who would supply this information with the Material Certificates. We have, however, installed ultra sonic testing equipment to spot check incoming material.

We submitted this specification to the supplier and obtained their concurrence before issue, so that at an early stage our Procurement and Inspection Departments were able to ensure suitable material availability to meet the manufacturing schedule.

Heat-treatment

It should be noted that stretcher stress relieved plate is received fully heat-treated and is machined in this condition.

Hand forgings

In covering stretcher stress relieved plate, we have accounted for approximately 85% of the heavy machined parts required for this program, the remaining 15% being covered by hand forgings.

Figure 5 illustrates why hand forgings were chosen

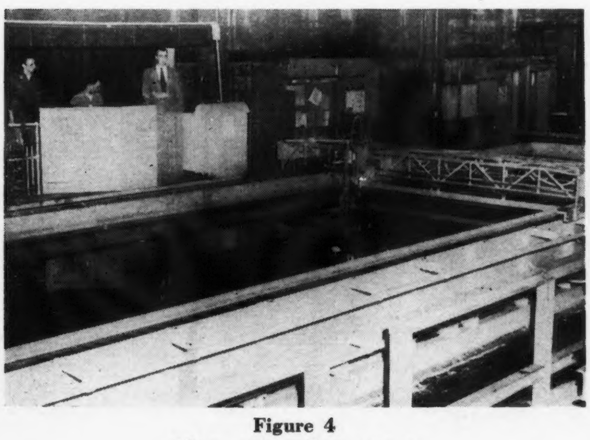
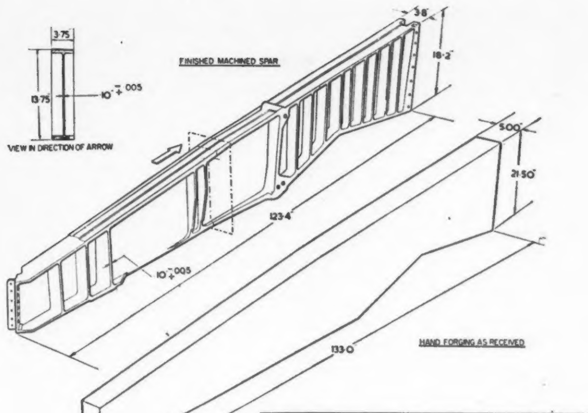


Figure 4
Ultra sonic reflectorscope



COST BASED ON 50 AC SETS	PRECISION FORGING	HAND FORGING
COST OF DIE PER PART	\$2380	\$ —
" " FORGING	\$ 360	\$1279
" " MACHINE	\$ 240	\$ 546
TOTAL COST	\$2980	\$1825

Figure 5
Wing spar and hand forged billet

instead of die forgings. It shows a typical wing spar as it would appear in the finished condition. You will note that web thickness of 0.10″ is called for and tolerances of ± 0.005″ are required by our Design Office for weight control purposes. To date, die forging is not practical for web thicknesses of less than 3/16″, so that a part manufactured from a die forging would require machining on all of these surfaces.

To illustrate the point further, here are cost comparisons based on 50 aircraft sets of parts made from die forgings and from hand forgings. In the case of the die forgings, the die cost is \$2,380 per part, the forging cost \$360, plus the machining cost \$240, making a total of \$2,980 per part. In the case of the hand forging, there is no die cost, a cost of \$1,279 for the forging, \$546 for machining, making a total of \$1,825, showing a saving of \$1,155 per part in favour of the hand forging.

Distortion

The problem of distortion during machining operations is very prevalent when using hand forgings, as shown in Figure 6. A comparatively new forging alloy 79S, when produced in the T8E13 condition, may be a solution to some of these distortion problems. Although at present its use is confined to hand forgings with two parallel sides and restricted to a maximum cross-sectional area of 72 sq in and a thickness of 6″, tests have indicated that heavier cuts may be taken on this material with much less distortion than that which occurs with 75S

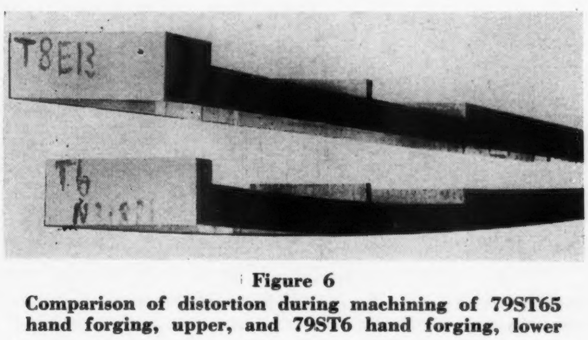


Figure 6
Comparison of distortion during machining of 79ST65 hand forging, upper, and 79ST6 hand forging, lower

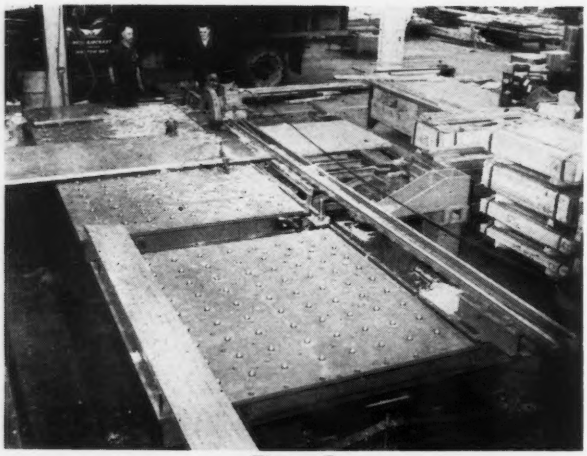


Figure 7
Saw for 3" x 20' plate

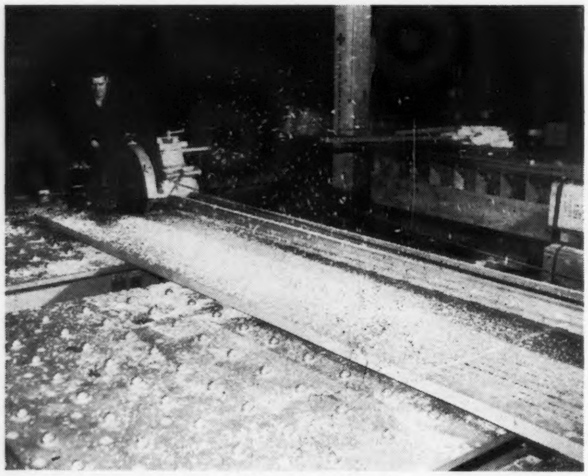


Figure 8
Saw for 3" x 20' plate

and 14S. Furthermore, the material is received in the T8E13 condition and requires no heat-treatment after machining. With hand forgings made from 75S or 14S, it is customary to rough machine forgings in the as fabricated condition leaving about ⅛" to ¼" on all surfaces for finish machining after heat-treatment.

MACHINE TOOLS

Special saw

Figures 7 and 8 show a special saw which was designed and built by Avro Aircraft. This machine has cutting capacity for plate 3" thick and lengths up to 20'. The average time for cutting this 3" by 20' plate is 15 minutes or 1½' per minute, giving an accuracy of ± 1/16" on the final width.

In preparing layout sketches for sawing, it is essential that the grain-flow is taken into consideration; where any deviation from longitudinal flow is specified on the Engineering part drawing, allowance is made in the width of the blank to permit swinging of the part centre line to the required angle. After sawing part blanks are numbered and marked with grain-flow direction. Just as a point of interest, it was considered economical to locate this saw in our Material Receiving Stores where all cutting operations are performed, thus minimizing our material handling problems.

Milling machines

When approaching the problem of heavy metal removal requirements along with complex shapes of heavy structural members, we were forced to leave behind the rules that governed conventional Machine Shop practice. Speeds, feeds and hp requirements have to be tailored to suit the light alloys. Consequently, speeds of 3,600 rpm, feeds of 100" per minute and up to 100 hp are required. Large component parts require similarly large machines.

Few machine tool suppliers have such machines available as standard; in fact it is rare that two or more aircraft companies will have the same ideas where procurement of machines is concerned. The machine tool manufacturers have, however, collaborated closely with the aircraft industry toward the establishment of standard specifications for large profile and skin milling machines.

Initially, on our program, we were concerned with procurement of machines capable of producing wing skin panels and, also, machines suitable for profile milling ribs, spars and formers. Both types of machine would be basically similar in function, the difference being mainly in size of work to be handled. At an early stage, Production Engineering and Design teams investigated production methods employed by other companies and collected together all available information on methods used. Basic design schemes, available for a number of major components, were analysed. Specifications for the necessary machines were then prepared, based on the preliminary scheme drawings and the information collected. It transpired that the machines required would be of copy milling type, with possibly some automatic tracing features.

Copy machining has, of course, in recent years become one of the most useful tools in the hands of the Production Engineer, with development proceeding at a rapid pace towards full automatic control.

Skin miller

The skin milling machine, shown in Figure 9, is now being installed at our plant and is equipped with automatic tracer control for both horizontal plane and rise and fall vertical plane movements. The following figures will give you some idea of the size of the machine.

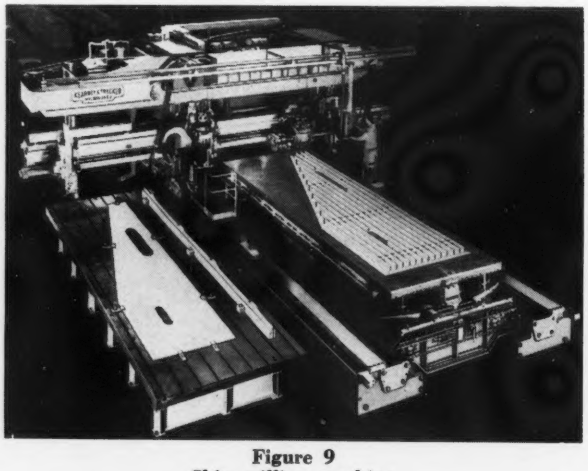


Figure 9
Skin milling machine

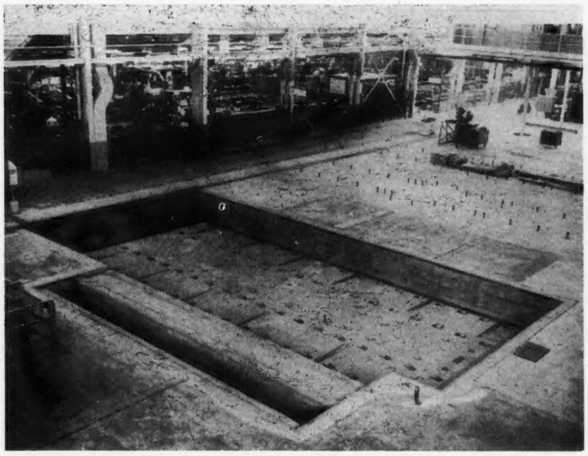


Figure 10
Foundation bed of the skin milling machine

Working surface of table — 9′ x 28′
Total weight — 100 tons
Weight of beam alone is 15 tons.

Machines of this size require solid foundations. Figure 10 serves better than words to illustrate the extent of the foundation required for this skin milling machine. Some 250 cu yd of concrete were used for this foundation.

You will observe that the machine is a gantry type. The tables stay put and the beam carrying the tracer and cutter heads moves over them. The advantages of this type of machine over the moving table type are the savings in floor space and full utilization of the work table.

The work table is equipped with a universal vacuum chuck. Holding large sheets flat during machining operations is essential and has been accomplished most successfully with vacuum pressure. The vacuum chuck on this skin miller has provision for tilting in two directions and can be rotated on the machine table to permit milling of compound tapers and converging stringers.

The tracer unit is located on an extension of the beam and follows the contour of templates which are mounted on the template table.

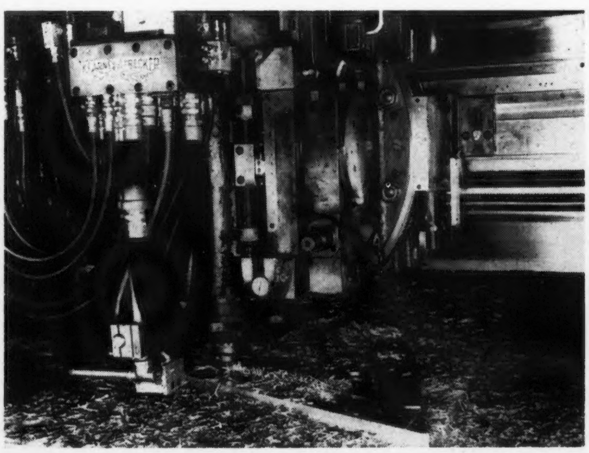


Figure 11
Vertical milling head: skin milling machine

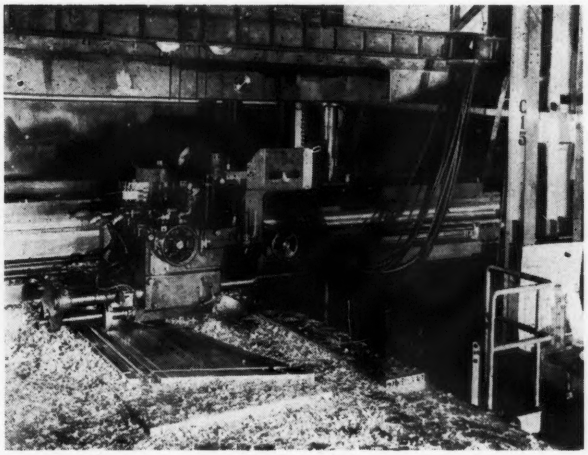


Figure 12
Horizontal milling head: skin milling machine

An indexing mechanism is provided whereby the horizontal cutter head can be indexed across the beam, whilst at the same time the stylus is indexed over the template table in a direct ratio. This is accomplished automatically so that on the completion of one cut both cutter and stylus are indexed across the machine in readiness for the next cut.

Two spindle heads are carried on the beam for vertical and horizontal milling. The vertical head (Figure 11) has provision for tilting the spindle in two directions.

Our Design Engineers have co-operated in eliminating, wherever possible, unnecessary end milling operations. Where end milling is unavoidable, mismatch for cutter blend out has been provided. All blend radii are large to enable use of sturdy cutters.

The present skin milling program necessitates use of the horizontal milling head (Figure 12) for the greater proportion of metal removal work on each panel. Some idea of the speed with which metal is removed can be gained from the following example of a horizontal milling cut. Employing rise and fall trace for thickness variation, width of cut 2½″, depth of cut 1½″, speed 3,600 rpm,

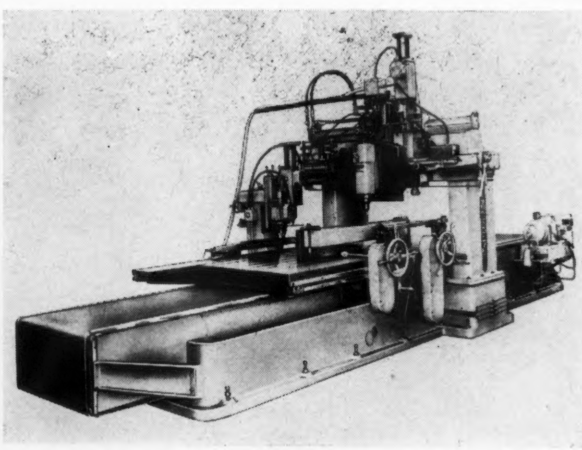


Figure 13
Vertical profile miller

feed 100″ per minute, cutter diameter 10″, results in a metal removal rate of 375 cu in per minute.

Vertical profile miller

It is intended that the large skin mill be supplemented by the smaller vertical profile milling machine, shown in Figure 13. This machine, whilst not as large as the skin miller, is capable of handling work of similar proportions (20′ long by 6′ wide). It also is equipped with horizontal and vertical tracing attachments and is capable of performing many of the same operations.

Unlike the skin mill, this machine is a planer type with moving table. The vertical type spindle head can be traversed across the beam and this in turn can be raised and lowered relative to the work table. For horizontal milling cuts, an attachment is mounted on the spindle nose.

Three positions are provided on the spindle head for attachment of the horizontal plane hydraulic tracer unit. With this arrangement, complete utilization of work table area is accomplished.

For rise and fall milling, a separate tracer unit is employed. This is mounted on a fixed column off the bed of the machine. No direct mechanical tie-in with the spindle exists, vertical movement during rise and fall cuts being effected through an electro-hydraulic system from the tracer unit.

Both templates and work are located on the machine table. On the large skin mill, a separate template table is provided. However, both machines are intended to carry out similar operations in the milling of skin panels and, though there are several differences between them, we have been able to utilize the same tooling.

Invo-mill

A third machine (Figure 14), which is also a gantry type machine but smaller and much simpler, will further supplement the skin mill. This machine is essentially a development of the power router. It will be used for end milling and routing operations only. Templates are mounted directly above the work as in sheet routing operations. Though this machine does not have all the automatic tracing features associated with the skin miller, it is felt that a considerable metal removal rate can be achieved. Since there are no tilting features, finishing operations are confined to parts in which pockets and peripheries are at right angles to the plane of the work table.

The working table on this machine can accommodate skins up to 20′ x 6′. Unlike the large skin mill, which

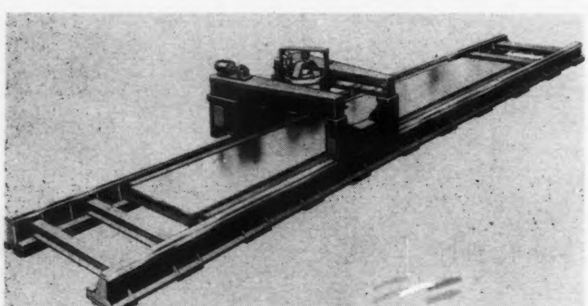


Figure 14
Gantry type power router

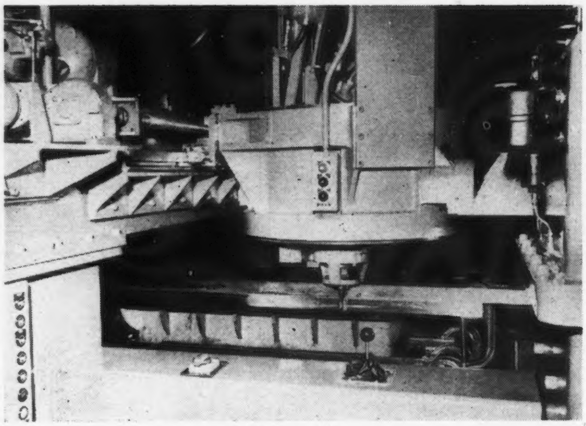


Figure 15
Cutter head—gantry type power router

has a single beam to the gantry, the Invo-mill has two fixed beams. The cutting spindle (Figure 15) is suspended between the two beams and can be rotated in its mounting. It is also provided with a pneumatic compensator, which assists the operator in maintaining contact with the template. The machine operator rides on the gantry and his primary function is to keep the template follower in contact with the template. Control of directional movement and rate of feed are effected by a simple joystick; the farther the joystick is moved in any direction, the greater is the speed of head travel in that direction. A second lever controls the rotation of the spindle head in its mounting and also the direction in which the compensator pressure is applied. Actual contact of the follower with the template and, therefore, proper positioning of the cutter in relation to the work is maintained by pneumatic pressure through the compensator.

Tilting head profile millers

Two additional machines, designed primarily for profile milling integrally stiffened ribs, spars and formers, are also in build at the present time. Both machines will be equipped with automatic tilting heads, as shown in Figure 16, to facilitate production of bevel angles on

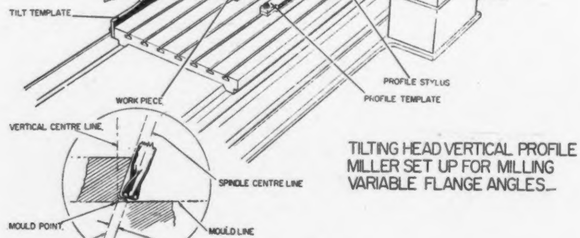


Figure 16
Tilting head profile miller

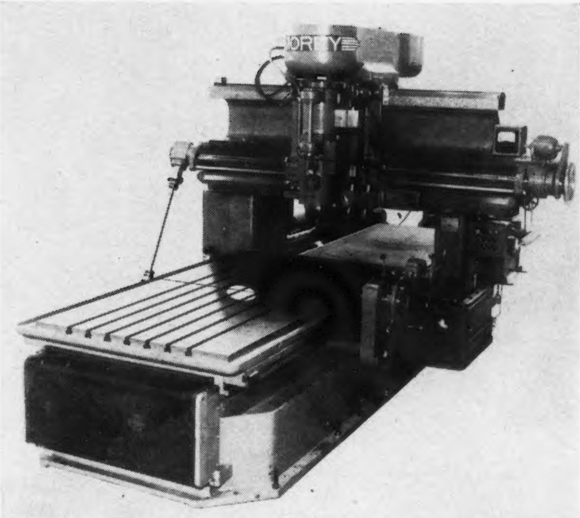


Figure 17
Hand controlled profile miller

aerofoil contoured flanges. An essential feature of the tilting head is the location of the point of tilt. To simplify template manufacture, this has been arranged below the cutter head and can be adjusted to coincide with the mould line of the part. Control of tilt angle is effected by a template mounted on the side of the machine table; linear rise and fall on the template is converted hydraulically into an angular movement at the cutting head.

One of these machines is virtually identical to the vertical profile milling machine, which I have just described, the only basic difference being in the provision of the tilting head and additional tracer unit to operate it. The remaining machine, shown in Figure 17, has the same tilting features but is much smaller in size. The working table is 4′ by 8′ and, on this machine, the beam is fixed; vertical adjustment of the spindle head is, therefore, effected through a slide behind the tilt quadrant.

Hand control

For 360° (horizontal plane) profiling we have, except in the case of the skin milling machines, specified hand control. Most automatic systems require the feed rate to be held at a speed slow enough to permit the tracer to negotiate sharp changes in direction at corners. With hand control, as shown in Figure 17, corners can be rounded at slow speed and, on straight or shallow contours, higher feeds can be employed.

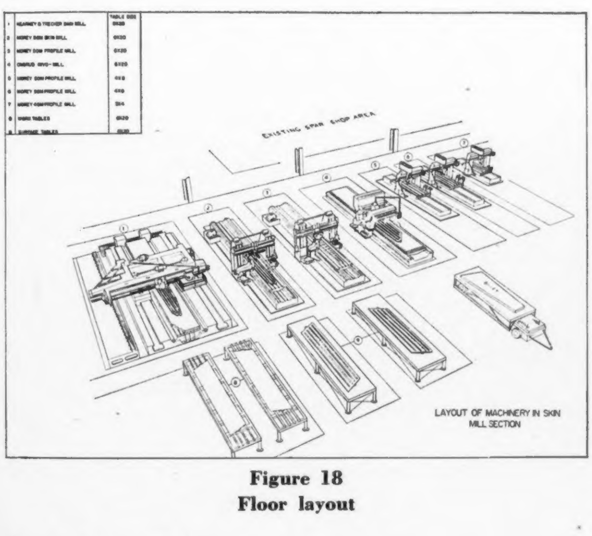


Figure 18
Floor layout

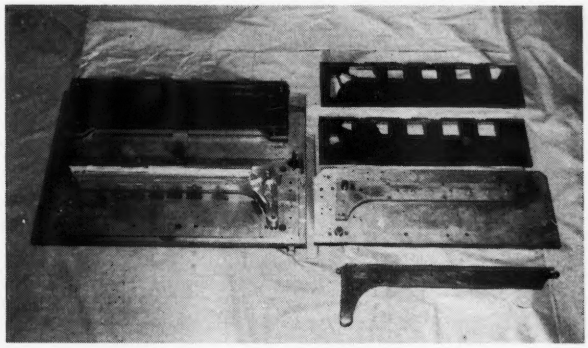


Figure 19
Profile milling tool family

Floor layout

Figure 18 shows the floor layout of the machines we have just reviewed. The prime reason for concentrating all this equipment in a single layout is to isolate the problems we know we shall be encountering in a program of this type. Storage space for the fixtures and templates adjacent to the machines is proposed to reduce handling problems.

For the skin panels and larger forged billets, special pallets and transport trolleys have been constructed. These provide for handling and storing of raw material and may be used as work tables for some of the initial operations. Special handling boxes for the smaller finished parts are a good insurance against the possibility of damage. A finished machined rib or spar is an expensive item and every precaution must be taken to avoid careless handling and consequent damage.

FIXTURES

Modern high speed aircraft require much closer control of assemblies to meet aerodynamic requirements. This entails more accuracy in detail part manufacture.

For profiling operations, robust fixture design is essential; both part and template locations should be on a common base. An example is shown in Figure 19.

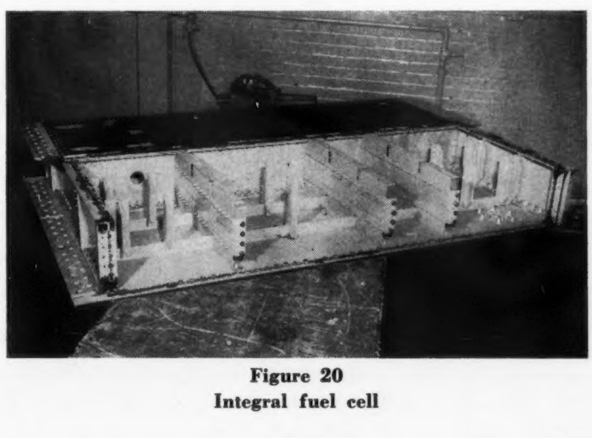


Figure 20
Integral fuel cell

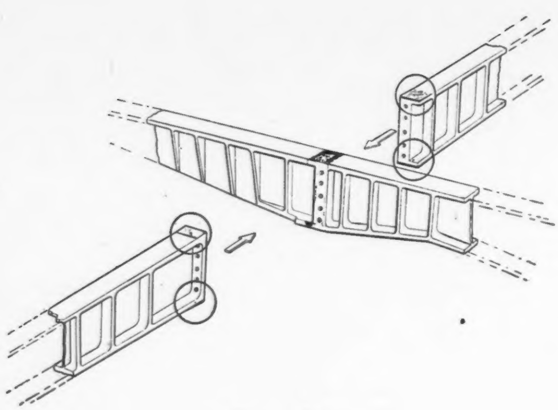


Figure 21
Blend out allowance for assembly matching

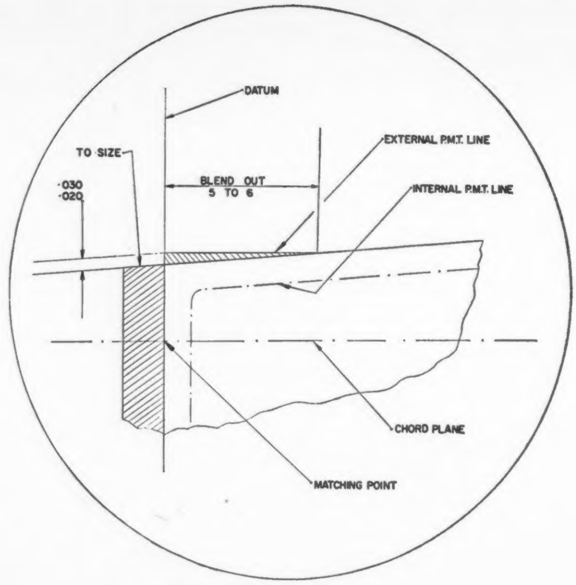


Figure 22
Blend out detail

Close co-ordination between pocket and external profile templates is mandatory to maintain flange and stiffener thicknesses and to eliminate tolerance build up. To this end, it is necessary that both Tool and Quality Inspection Departments keep a close watch on the tools throughout the build period. At this time, inspection facilities can be incorporated in the fixture design, thus permitting inspection of first off parts in the fixtures, whilst they are on the machine. This obviates the need for inspection set-ups in the view room and provides a useful check on the accuracy of machine settings. In many cases, the external shape of a finished part can only be defined by a loft line or layout line. It is therefore only possible to check such shapes to templates. By reducing the number of templates and using the one provided with the fixture, it is possible to reduce errors.

FUEL-TIGHT JOINTS—BLEND OUT ALLOWANCE

Concurrently with the trend to integral structural members, there is also the requirement for the fuel-tight sealing of some areas of skins and structure to provide Integral Fuel Cells, as shown in Figure 20. This further complicates the assembly problems since, to achieve efficient sealing, gaps at mating surfaces of fuel-tight joints must not exceed three thousandth of an inch before application of the sealer. In spite of matched contour templates, it is inevitable that mismatch will occur due to machining tolerances.

Correct and final matching can only be achieved on assembly by metal removal or by area build up. We decided that metal removal at assembly would be the most practical approach. This is accomplished by machining the span-wise members to their correct size and leaving a wedge of material (Figure 21) on the chord-wise ribs where these ribs join together. The amount of metal left on the chord-wise ribs is between 0.020″ and 0.030″ thick and blends out to correct size 5″ to 6″ from the joint (Figure 22). This blending is done at final assembly with a portable hand sander.

CONCLUSION

Only a few highlights have been touched on in this paper. The detail problems that have been worked out have made this an extremely interesting program for all of us. Completion of the work that still lies ahead I am sure will be equally interesting; keeping current with the vast amount of progress being made on electronic machine tool automation and adapting these advances to production makes the outlook for the future most promising.

CORRIGENDUM

Dr. Bull has pointed out an error in his paper entitled "Some Aerodynamic Studies in the C.A.R.D.E. Aeroballistics Range" in the May issue of the Journal.

In the List of Symbois appearing on page 157, please change the definition of

C_M to read "pitching moment coefficient based on body cross-sectional area"

C_N to read "total normal force coefficient based on body cross-sectional area".

THE BIRTH AND EVOLUTION OF THE GAS TURBINE†

by V. E. Crompton*

Orenda Engines Limited

THE JET AGE BEGINS

THE efforts leading to the development of the aircraft gas turbine engine were stimulated by the realization in the 1920's, by Great Britain, Germany and Italy, that very high speeds and long range required flight at great heights; 500 mph was conceived at heights where the air was a quarter the density of air at sea level. This thinking was done at the time when maximum aircraft speeds were of the order of 150 miles per hour.

In considering how to attain these high speeds and altitudes, using the conventional propeller driven by a piston engine, it was at once seen that rarification of the atmosphere resulted in rapid decrease of propulsive efficiency of the propeller, which is required to accelerate a large mass of air at a relatively low velocity.

The theory that gases might be ejected from rest under pressure in a chamber through a nozzle, providing a reaction which is equal and opposite to the force giving the gas its kinetic energy in the nozzle, appeared in an article written in 1928 by Flight Cadet F. W. Whittle, titled "Speculation". From this reaction theory, that basically the gas turbine accelerates a small mass of air to a high velocity by means of heat energy, the jet age began.

How this was accomplished in Great Britain is the story of Sir Frank Whittle, K.B.E., and Power Jets Limited.

EARLY PROGRESS IN GREAT BRITAIN

Whittle from his very early student days was obsessed with the idea of a turbine reaction engine. Realizing that steam was out of the question due to weight, he turned to gases as his working fluid and filed the first provisional specification for a turbine driven jet engine. This was placed before the British Air Ministry, who advised Whittle that they were not interested. Attempts were made between 1930-1932 to interest the British Thomson-Houston Co., Rugby, and Armstrong Siddeley Motors of Coventry, but these companies did not consider the proposition practical and would not back the invention. Attempts were made to raise working capital

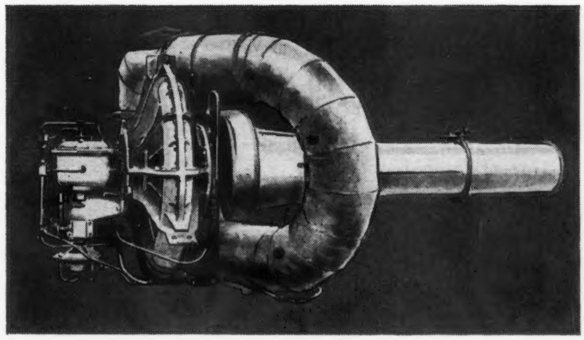


Figure 1
Whittle's first experimental engine

for private development. This proved very difficult since original patents, when applied for by a serving R.A.F. officer, are retained by the British Government as "Free Crown User". In 1932, the master patent lapsed through lack of support and funds.

Whittle was very discouraged but, having an outstanding tenacity of purpose, he continued to explore further fields. Eventually, through the aid of his friends, a small amount of money was forthcoming and in 1936 Power Jets Limited was incorporated as a private company. Contracts were placed with the British Thomson-Houston Co. on a cost-plus basis for design drawings of an experimental engine, this method of payment being the only condition on which they would undertake the work since they considered the idea somewhat fantastic.

The original designs for the engine were to be:

RPM 17,750

Impeller, 19″ Diameter, Centrifugal, Efficiency 80%, Pressure Ratio 4:1

Turbine Dia. 16½″

Air Flow 1,500 lb/min

Towards the end of 1936, the initial stages of manufacture and combustion experiments were started. By the end of the year a total of about $9,000 had been spent on the total project.

It was not until 1937 that the first experimental engine ran (Figure 1). This was not without incident. The single combustion chamber proved unstable and the

†Received 25th April 1956.

*Assistant to Vice-President, Sales and Service.

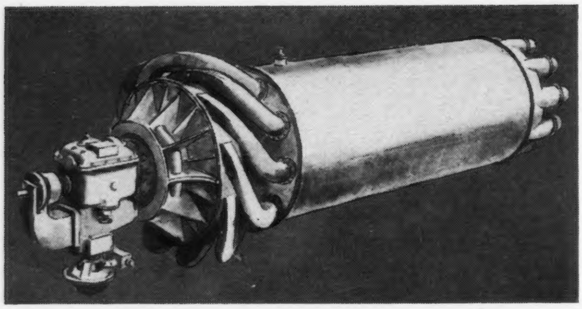


Figure 2
Mockup of Whittle's second experimental engine
Single combustion chamber

engine ran out of control, much to the consternation of many senior company officials. This excited in some of those present a sudden desire to depart – bringing to mind a famous comment made by one of the shop officials shortly after the event, "It's no good running away, sir. If it's coming your way, it will catch you". This engine design was abandoned having proved one thing – that it would most certainly accelerate.

The next engine was then designed, still with a single combustion chamber, the gases being ducted, after passing through the combustion chamber and the turbine, back through the outer casing of the combustion chamber by way of ten organ pipes (Figure 2). After considerable modification this engine ran in April 1938 for 1 hour at 8,200 rpm. Then, in May 1938, after a continuous run of 1 hour 45 minutes at 13,000 rpm, giving a thrust of 480 lb (design expectation 550 lb), a disastrous turbine failure occurred. Although this failure was a setback, in July of the same year the Directorate of Scientific Research (U.K.) admitted quantitative experimental verification of this principle of gas turbine propulsion. The total expenditure to date was in the neighbourhood of $27,000. Failure of the second engine was due to a design error and a third re-design was commenced, which for the first time showed the more modern concept with can combustion (reverse flow) (Figure 3). In the period 1938 to mid-1939 this engine was passing through a series of tests, rpm increasing from 8,000 to 17,000. The Directorate of Scientific Research (U.K.) was now convinced that this was the basis for a gas turbine aero-engine. In August 1939 the British Air Ministry placed its first contract for a flight engine designated W. 1 (thrust 1,240 lb) and a more powerful engine W. 2 (thrust 1,600 lb) with Power Jets Limited.

To provide a flying test bed for the Power Jets W. 1 gas turbine engine, an additional contract was placed with the Gloster Aircraft Company for a suitable aircraft designated the Gloster Whittle E28/39.

At about this time the second world war was declared; security problems arose of a rather complex nature. It was thought by the local police force at the Power Jets Experimental Establishment at Lutterworth that Irish Republican Army terrorists were making bombs. To overcome this suspicion, word was given out to the local inhabitants that a super vacuum cleaner was being developed.

Towards the end of 1939 the design of the W. 1 was well advanced and the personnel of Power Jets Limited was increased from two (which incidentally included the writer), plus a boy and a dog, to three, plus a boy, watchman and a dog to deal with the situation.

Under the impetus of the war and the successful performance of engines on test, the Gloster Aircraft Company were instructed to proceed with the design of a twin jet engined interceptor fighter and a mock-up of the Power Jets W. 1 engine was forwarded to this company for installation study.

To meet the power requirements for the Gloster Aircraft, the F9/40 Meteor, design was commenced on the Power Jets W. 2B, with a static thrust of 1,800 lb, and tentative planning conceived a total of 160 engines and 80 aircraft a month. The total expenditure on gas turbine development to this date is estimated at $140,000.

During 1941 testing continued, using the W. 1(X) experimental engine and accumulating 40 hours running time in the first three months, which included 8 hours at 14,500 rpm and 10 hours at 14,000 rpm.

In April 1941 the Gloster Whittle E28/39 was completed; taxiing trials were completed with the W. 1(X) engine; at the same time, the W. 1 flight engine completed its 25 hour special category test – 17,000 rpm, thrust 1,000 lb – and the engine was cleared by the British Ministry of Aircraft Production for 10 hours flight.

On May 15, 1941, the W. 1 engine, developed by Power Jets Limited and built by British Thomson-Houston, was flight tested at Cranwell, England, in the Gloster E28/39; it was airborne for 17 minutes with F/L P. E. G. Sayer, R.A.F., as test pilot. A total flying time of 10 hours 28 minutes was completed without incident. Top speed was 370 mph at 25,000 ft (17,000 rpm, thrust 1,000 lb). At this date, the total test running time on the whole project from its inception was 292 hours.

From this beginning the jet era took shape; the more important British engine manufacturers, who were at first skeptical, now awoke to the fact that the turbojet engine was here to stay and the race began. This paper is no place to discuss this race, but for many months there were extensive meetings with Rolls-Royce Limited, the Rover Company and DeHavilland Limited. These companies put forward their proposals, one of which resulted in the birth of the Goblin-engined Vampire; Rolls-Royce took over the work of the Rover Company in production of turbojet engines for the Meteor, the Rover B. 23 being designated the RR Welland, and design of the RR Derwent based on the Rover B. 26 began.

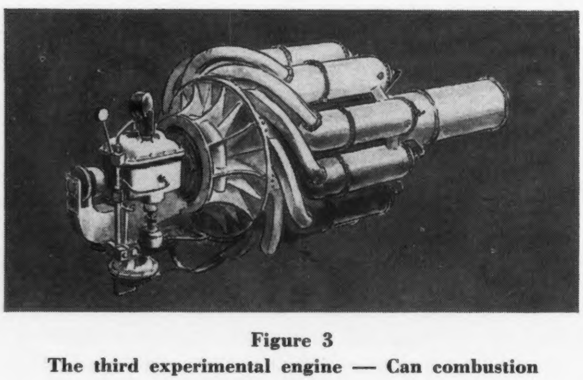


Figure 3
The third experimental engine — Can combustion

PROGRESS IN THE UNITED STATES OF AMERICA

In October 1941, the Power Jets W. 1 (X) engine, together with all appropriate drawings and a small technical team, was sent by air to the General Electric Company at Lynn, Mass., U.S.A.

It is interesting to record that General Electric had their first turbojet engine on test by April 1942 and, in October of the same year, the Bell XP-59A powered by two General Electric 1-A turbojets was officially test flown at Muroc Lake.

Westinghouse were developing a turbo jet similar to the R.A.E. Metropolitan Vickers F. 2 (axial-flow).

A turbojet engine test plant, high altitude condition, was under construction at Wright Field, Dayton.

General Electric were planning to produce 1,000 engines a month.

CHRONOLOGICAL SURVEY

At the same time these British and American developments were progressing, the Germans and to some extent the Italians had run in parallel along a similar path.

The following chronological summary is believed to be a true and factual record:

1791	British	John Barber took out the first patent for a "Gas Turbine" – the first time a patent was taken out for an engine of this sort.
1910	French	Up to this date a number of industrial low efficiency gas turbine engines had been produced from 30 to 500 bhp. These were largely of French origin such as Rateau Lemale and Armengaud.
Prior to 1928		Scientists in Britain, U.S.A., Germany, France and Italy were experimenting and investigating possibilities of propulsion by jet reaction.
1928	British	Flight Cadet Frank Whittle presented at Cranwell an R.A.F. thesis on future aircraft developments. He discussed, as separate entities, gas turbine power units and jet propulsion systems.
1929	British	Whittle conceived the idea of using the gas turbine for jet propulsion. A. A. Griffith at R.A.E., Farnborough, proposed a counter-rotating turbine power unit for airscrew propulsion.
1930	British	Whittle patented a design based on the principle of using a gas turbine for jet propulsion.
1930	German	Preliminary research in gas turbine compressors was begun by Professor Prandtl of Junkers.
1935	German	Hans von Ohain took out patents on aircraft gas turbines.
1936	British	In March, Power Jets Limited was formed to develop Whittle's turbojet with centrifugal compressor. In July, the R.A.E. began development of the eight-stage axial-flow compressor "Anne".
	American	General Electric were developing the turbo supercharger for piston engines.
1937	British	In March, H. Constant (R.A.E.) presented a plan for an axial-flow turbine for propeller drive, which was named B10, built by Metropolitan Vickers and test run in October 1940.
	German	In the same month, von Ohain-Heinkel unit ran on test bench.
1937-38	British	In April 1937, Whittle experimental unit was tested at BTH, Rugby. Two revised versions were tested in April and October 1938.
1938	American	A five year plan for development of gas turbines was initiated at Wright Field and resulted in preliminary contracts to General Electric and Allis-Chalmers.
1938	British	The R.A.E. designed a turbo-compressor based on the 1929 scheme by Dr. Griffith. Built by Armstrong Siddeley in 1938-39 and tested in 1940.
1939	German	Hans A. Mauch of the German Air Ministry (RLM) placed contracts with Junkers for the Jumbo-004 and Bavarian Motor Works for the BMW-003.
	British	In July, contracts were given to Power Jets Limited for the Whittle flight engine W. 1 (to be built by British Thomson-Houston) and to Gloster Aircraft for the experimental aeroplane E28/39.
	German	On 27 August, the Heinkel He S 3 turbojet engine was flight tested in the experimental jet aircraft HE-178. This was the earliest aircraft to fly powered by a turbojet unit. It was not a great success, however, because the aircraft was slow and the life of the engine very short.
1940	German	Early in the year the BMW-003 was test run and found unsatisfactory.
	British	The Rover Company began production of Power Jets W. 2 engine which led to W2B23 (prototype of Rolls-Royce Welland) and W2B26 (prototype of Derwent).
1940	Italian	On 27 August, an Italian Caproni-Campini CC2 flew. This had a radial engine, two-stage centrifugal compressor and jet. The engine was of crude design and the flight lasted only ten minutes. In November 1941, another version flew from Milan to Rome. Nothing more was heard of Italian jets and they were not met in action during the war.
	German	In November, a Jumo-004 was bench tested.
1941	German	In the spring two BMW-003 engines were flown in the Me-262 fighter. In the summer it was tested in the Me-110 flying test bed. RLM supplied Heinkel with the design of the Heinkel-Hirth O11. Development was

		slow, bench test being reached in 1944; not flight tested before end of hostilities.
	American	John K. Northrop presented turbojet proposal to U.S. Navy and got go-ahead. Navy placed contracts for complete design study.
	British	In April, the Whittle W.1 engine was given a 25 hour bench test to clear it for a test flight. In the same month, the Whittle W.1(X) was used for taxiing runs in the Gloster E28/39. During these, the aircraft actually left the ground for a few seconds.
		On 15 May, the W.1 engine, developed by Power Jets and built by British Thomson-Houston, was flight tested at Cranwell in the Gloster E28/39, being airborne for 17 minutes with F/L P. E. G. Sayer at the controls. This marked the first successful flight of an aircraft powered by a turbojet engine.
1941	German	The Jumo-004 was tested in a modified Me-110 about a year after its first bench testing (November 1940).
1942	British	Power Jets W2/500 first run.
	German	On 15 March, Junkers Jumo-004, was tested in a Me-110 flying test bed.
		On 18 July, the Jumo-004B was test flown in an Me-262, first jet-propelled combat aircraft to take to the air, operational in Luftwaffe fighter squadrons two years later.
	American	In October, Bell XP-59A, powered by two General Electric 1-A turbojets, (developed from the Power Jets W.1(X), was officially test flown. This was the first successful U.S. jet aircraft.
1943	British	On 1 March, the Rover B23 engine was flown in the Gloster E28/39.
		On 3 March, the Gloster Meteor was first flown on two deHavilland Goblin turbojets.
1943	British	In April, Rolls-Royce took over the work of the Rover Company in production of jet engines for the Meteor. An improved version of the B23 designated the RR Welland passed 100 hour test. Design of the RR Derwent, based on the Rover B26, began. In the same month, Armstrong Siddeley tested the ASX, a 14-stage axial-flow compressor, 2-stage turbine.
		On 12 June, the Gloster Meteor was flown on two RR Welland turbojets.
1944	British	On 21 July, the first operational Gloster Meteors went into service with R.A.F. No. 616 Squadron and into action against V-1 buzz bombs.
1945	British	On 7 November, a Meteor IV, powered by two Derwent Vs, (Group Captain Wilson, R.A.F.), broke the world's speed record with three flights over a closed course averaging 975 kph (606 mph).
1946	British	On 7 September, a Gloster EE-549 Star Meteor, (Group Captain Donaldson, R.A.F.), achieved a new world speed record of 991 kph (616 mph). This represented a Mach number of slightly over 0.81.

EVOLUTION

The reaction engine has branched into these main classifications:

Ram jets
Pulse jets
Turbojets, centrifugal and axial compressor, single and twin spool, with and without re-heat, and by-pass
Turboprops
Gas Producers
Rockets
Rocket and Turbojet combinations

Each of these classifications have their specific place and application in the forthcoming air age.

Turbojet-Turboprop Comparison

In a turbojet, the energy of the gas stream is reduced through the turbine only by the amount of heat energy required to drive the compressor, the remaining energy being exhausted to atmosphere.

In the turboprop, as much power as possible is transmitted from the turbine to the propeller by designing turbine blades to obtain the maximum pressure drop across each stage. In practice it is not desirable to take all the kinetic energy from the gas stream, the resultant thrust being utilized in addition to propeller power.

Twin Spool Compressor Concept

The character of the turbojet engine is basically determined by its compressor. With the advent of the supersonic aircraft, requiring higher propulsive power coupled with flexibility, the twin spool compressor concept has been developed.

With a single shaft engine with fixed geometry compressor aiming at a low specific fuel and consequently a high pressure ratio, flexibility is very difficult, if not impossible, to attain. At any specifically stated operating point, the design pressure ratio, air mass flow, and rpm can be obtained with the compressor blading operating at an incidence giving low aerodynamic losses. In engines operating with pressure ratios greater than 7 or 8:1 when the compressor is functioning away from its design point, in particular at low speeds, the incidence of the blades moves into an aerodynamic high loss region, in that the first stages in the front of the compressor tend to stall due to excessive positive incidence, while the last stages tend to run at excessive negative incidence.

In compressor design, early signs of excessive pressure ratio are difficult starting and poor acceleration. Palliatives are:

(1) Variable geometry compressor. Often it is sufficient to vary the inlet guide vane angle, but in some cases other stator rows must be also variable.
(2) Blow-off valves fitted at compressor outlet or part way along compressor to reduce mass air flow through later stages.

In order to obtain higher pressure ratios than 10:1 and use them usefully, the twin spool layout came into being.

With this type of compressor, high and low pressure rotors are mechanically separate and free to run at different speeds. Balanced and compatible air flows can be obtained throughout the length of the compressor under all running conditions without need for variable incidence inlet guide vanes, or blow-off valves. The relative temperature drops across LP and HP turbines automatically vary so that below design speed the LP compressor rotor runs at a lower rpm than the HP compressor rotor; consequently, the lower airflow incidences for the front stages and higher incidence flow for the rear end of the compressor are attained.

By-pass Engines

As an interim approach between the utilization of the turboprop and the turbojet, for long hauls with low fuel consumption the by-pass engine has been introduced. This concept basically is to tap off some medium pressure air from the compressor and by-pass it into the exhaust stream, with the effect of increasing the mass flow of the exhaust gases, slightly cooling them in the process. The advantage claimed is a reduced rate of fuel consumption per pound of thrust obtained. A higher cycle efficiency, obtained by operating at a higher turbine inlet temperature, combined with an improved propulsive efficiency derived from a lower jet pipe temperature, gives a by-pass engine its advantage in specific fuel consumption over the straight jet. Another main advantage is the fundamentally lower noise level compared with the straight jet.

Reverse Thrust

A serious problem is presented by the length of landing run required by aircraft with high wing loading, when retaining sufficient power immediately available to get out of any emergencies which may arise.

In the past, with the piston engine it was common practice to reverse the pitch of the propeller to obtain the required drag; with the propeller turbine engine, such as the single shaft, two-stage centrifugal compressor, Rolls Royce "Dart", a large pumping power consumption, due to the quantity of air being passed through the compressor, provides a high drag when the propeller is windmilling. This drag produces reverse thrust at the initial high speed stage of the landing run. With a twin spool arrangement in a turboprop, the propeller is only connected to one stage and the engine would have to be fitted with a reversible propeller.

On a turbojet, reverse thrust is attained by deflecting the jet in a forward direction. A full reversal is unnecessary and not practicable, one of the problems being that the engine would breathe its own exhaust gases. Up to a 45° reversal will attain 70% of rated thrust in reverse. Reverse thrust has been approached in several ways, but the forces to contend with are considerable, entailing a weight penalty.

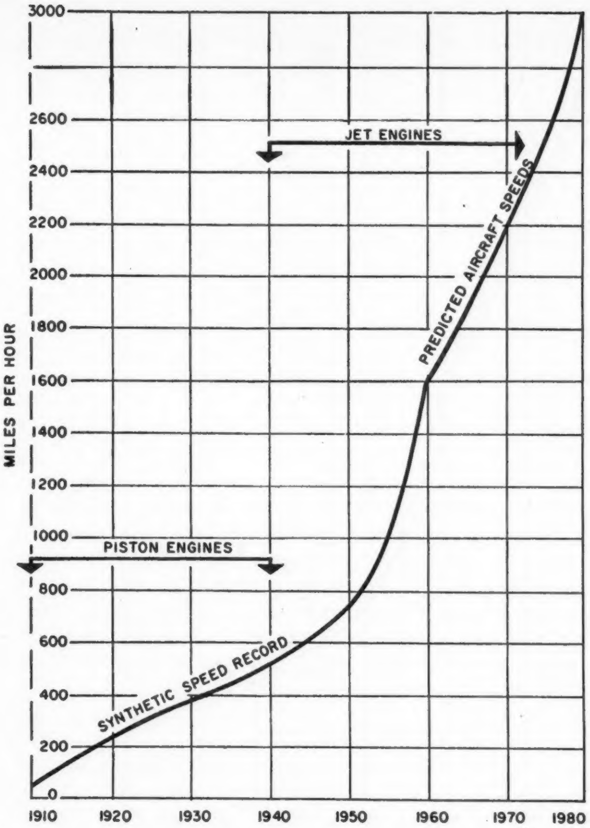


Figure 4
Aircraft speeds — attained and predicted

THE FUTURE

What is ahead can only be estimated on the assumption that technical progress follows a geometric progression pattern based on what has already been accomplished.

Founded on existing speed records, the progressive pattern indicates a speed of 1,600 mph by 1960, this having already been demonstrated by the Bell X-2. Commencing at this stage and superimposing the geometric progression of the next phase of development of the turbojet power plant, it is indicated that the possible speed of jet powered aircraft will be in the order of 3,000 mph by 1980. This is demonstrated in Figure 4.

BIBLIOGRAPHY

(1) Leslie E. Neville and N. F. Silsbee—*Jet Propulsion Progress.*
(2) Rodney Tilley—*Success Story.*
(3) Sir Frank Whittle, K.B.E.—*Jet.*
(4) S. H. Deeks—*Analysis of Aviation Trends.*
(5) F. H. Keast—*A Study of the Axial Flow Jet Engine.*
(6) The chronological summary is mostly quoted from Hawker Siddeley Group—*Jet Power History.*

FILM LIST

The Institute proposes to prepare a List of Aviation Films for use by its Branches and Sections and by other organizations interested in obtaining films on aeronautical subjects. This work is being undertaken in collaboration with the Air Industries and Transport Association and the Canadian Owners and Pilots Association and, therefore, the List will not be confined to engineering topics but will include films on flying training, meteorology, survival and other aspects of aviation.

Several lists of aviation films are already available, but they include a great deal of obsolete material and they probably omit many interesting technical films, held by research organizations and the like, which might be procurable by special arrangement for showing to restricted and qualified audiences. Furthermore, it is not possible to classify films intelligently from the titles and brief descriptions usually given in these lists. Consequently any consolidation of the existing lists would contribute nothing: the proposed List must be based upon first-hand reports.

Since it is clearly impossible to set up a Selection Committee to review, assess and classify all the films which might be of interest, all members of the Institute are asked to cooperate in this work. Any member having personal knowledge of a film which, in his opinion, would be *instructive* or *of current interest* to an aviation audience is asked to send particulars to the Secretary of the Institute.

It is proposed to revise the List each year, retaining some of the films previously listed, discarding those which are obsolescent and, of course, adding new films reported since the previous issue. By this means, it is hoped that the Institute's List, though it may be short, will always be up to date and significant.

THESE ARE THE PARTICULARS REQUIRED. PLEASE BE SURE THAT YOU GIVE THEM ALL.

(1) Title.
(2) Year produced (approximate).
(3) Size (8 mm or 16 mm).
(4) Running time.
(5) Colour or black and white.
(6) Sound or silent.
(7) From whom it may be obtained and cost (if any).
(8) Description, of not more than 30 words.
(9) Category—one of the following ten.

- (*a*) Engineering, Manufacture and Maintenance —Aeronautical
- (*b*) Engineering, Manufacture and Maintenance —Power-plant
- (*c*) Engineering, Manufacture and Maintenance —Systems
- (*d*) Engineering, Manufacture and Maintenance —Materials
- (*e*) Engineering, Manufacture and Maintenance —Electronic
- (*f*) Flying—Training
- (*g*) Flying—Techniques
- (*h*) Flying—Survival
- (*i*) Flying—Meteorology and Navigation
- (*j*) General Interest

Note: The last category should be used with discretion and should not be applied to a film which is not primarily concerned with aviation.

C.A.I. LOG

SECRETARY'S LETTER

R.Ae.S. AND I.A.S.

SINCE the formation of the C.A.I. I have visited I.A.S. Headquarters in New York on several occasions but I had not visited the R.Ae.S. until last June, when some personal business took me over to England. I made the most of the opportunity to see Dr. Ballantyne, the Secretary, and had very useful conversations with him and with Mr. Lumsden, Mr. Dunsby and Mr. Barrett of the R.Ae.S. staff.

More recently, in August, I spent the best part of two days at I.A.S. Headquarters in New York. The principal purpose of my visit was to discuss the arrangements for the forthcoming International Meeting but, of course, I discussed almost everything else as well and came away loaded with new ideas. In my experience the officers and staff of the I.A.S. are usually flitting all over the world but this time I was lucky enough to catch nearly all of them at home; Mr. Paul Johnston, the Director; Mr. Dexter, the Secretary; Mr. Shrader, Mr. Meskel, Mr. Ryan, Mr. Judge and Mr. Bidwell—all gave me a great deal of their time and advice.

While I was there I also met Major Lester Gardner, who organized the I.A.S. in 1932. He retired from active work just after the war; and he celebrated his 80th birthday this year. Major Gardner was most interested to hear about the C.A.I. and of our efforts, echoing his own some twenty years later.

In these discussions with our parent societies, British and American, I am always most impressed by their real enthusiasm for the C.A.I. They read our Journal, probably much more thoroughly than most of our own members do, and they take a close interest in all our doings. Of course, from their extensive experience they can warn us of many pitfalls and offer solutions to many of our problems but I am often rather surprised, and not a little relieved, to find that some of our problems are still their problems too. Such bogeys as the handling of classified information, certain aspects of the grading of members, the provision of adequate services to specialists and of course the perennial problem of "the shortage of engineers" are as familiar to them as they are to us. They contrive to live uncomfortably with these spectres and, though they have devised no completely satisfactory ways of laying them, it is always helpful to discuss them.

FILM LIST

On the opposite page you will find an appeal to all our members to cooperate in the preparation of a C.A.I. Film List. Existing lists seem to have been compiled with the idea of listing every film remotely associated with aviation. As lists they are splendid but they are very bewildering to anyone wishing to procure a film suitable for some specific occasion. And I am sure that these existing lists omit a class of film which would be very instructive and interesting to C.A.I. audiences; I refer to the rather rough and ready "research" films held by many laboratories and engineering departments, prepared without great attention to the quality of the photography to show what happens when a window blows out of a pressurized cabin, when an engine catches fire, and that sort of thing. Surely some of these films could be made available to our rather special audiences; at any rate it would be worth trying to find out about them. Their inclusion would make our List somewhat unusual and certainly more valuable, technically, than most of the others.

Every member is asked to help in this project. It is one which no committee or other small group (let alone Headquarters staff) can handle on their own.

THE NEW SEASON

The Institute is now embarking on its new season of activities. All the Branches promise to have full and interesting programmes. In November the annual International Meeting with the I.A.S. will be held in Toronto. In February it is planned to hold a one-day Institute meeting in Winnipeg. The Annual General Meeting will be held in May.

Probably in the near future I shall be able to report the Council's plans for Specialist Sections; details are now nearly completed but it would be premature to discuss them. This innovation may prove to be an important step forward in the service which the Institute can render to its members.

I hope too that the coming season will see the development of additional Student Sections and even additional Branches.

Quite a programme!

BRANCHES

BRANCH EXECUTIVES 1956-57

	Montreal	*Ottawa*	*Toronto*	*Winnipeg*	*Edmonton*	*Vancouver*
Chairman	T. A. Harvie	M. S. Kuhring	F. H. Keast	J. J. Eden	J. G. Portlock	I. A. Gray
Past Chairman	A/V/M A. L. James	J. L. Orr	W/C J. N. Brough	W. S. Haggett	—	H. D. Cameron
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BRANCH SECRETARIES

The addresses of the Branch Secretaries are as follows:—

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Edmonton

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EDMONTON, Alta.
Phone—Office: 48-151
Home: 75-904

Vancouver

Mr. R. J. McWilliams,
4243 Winnifred St.,
SOUTH BURNABY, B.C.
Phone—Office: DUpoint 1242
Local 106
Home: DExter 5764L

BRANCH PROGRAMMES

The following particulars of Branch programmes have been received to date. At present many of the details are only tentative but the dates are probably firm.

Toronto

12 September
International Gliding Meeting Report
J. W. Ames

10 October
Cold Weather Operation of Aircraft

14 November
Field Projects of Defence Research Medical Laboratories

12 December
Proprietary Equipment

9 January
Flight Test Insrtumentation
U.S. speaker from Edwards Air Force Base

Vancouver

9 October
Social night

The remainder of the Vancouver programme is not settled but the meeting dates are as follows:

17 September
30 October
14 November
13 December
18 January

Winnipeg

25 September
Dew Line Operations
Central Northern Airways

30 October
Aircraft Accessories
The Garrett Manufacturing Corp. of Canada, Ltd.

27 November
Satellites and Space Travel
The Goodyear Aircraft Corporation, U.S.A.

18 December
Dinner Dance

29 January
Helicopters—Manufacture and Operation
Canadian Pratt & Whitney Aircraft Co. Ltd.

NEW BRANCH

Cold Lake

The Council has approved the formation of a Branch at Cold Lake, Alberta. The membership of the Branch comprises the R.C.A.F. and civilian personnel at the R.C.A.F. Station who, as an interim organization, have held several meetings already during the spring and early summer.

Although the R.C.A.F. Station at Cold Lake is assuming some importance, it is

rather remote and for a while the Branch may experience some difficulty in obtaining speakers. Members of the Institute visiting Cold Lake in the course of their ordinary business should bear this point in mind and, if circumstances permit, they should try to talk to the Branch while they are there. Mr. R. W. Ellard is acting as Secretary of the Branch at the present time and all offers to speak should be addressed to him at Box 1010, MPO 503, Grande Centre, Alta.

NEWS

Vancouver—Reported by R. J. McWilliams

May Meeting

Thirty-two members and guests attended a meeting held on the 15th May at 20.00 hours in the C.P.A.L. Main Classroom. The speaker for the evening, Mr. P. L. Kenney, Electrical Engineer, C.P.A.L., and his subject "The Transistor", were introduced by Mr. R. N. McCollum, Sperry.

Mr. Kenney opened his talk with a review of the history of the development of the transistor. Of particular interest was the development of synthetic cystals leading to the germanium rectifier and then the discovery that the use of a second contact transforms the rectifier into an amplifier. It is here that we find the secret of the transitor, a lightweight miniature component, which efficiently provides a power gain of the order of 100 to 1. The delay in making the transistor general knowledge was attributed to war-time secrecy and the fact that, following the release of information, technical literature was flooded with an abundance of "flute music", understandable only to the mathematician and researcher.

With the aid of simple diagrams, Mr. Kenney described "how" the transistor functioned and whetted our appetite for the subsequent description as to "why" it worked. Much credit is due to Mr. Kenney for the skilful way in which he led his audience through the atomic theory explaining the operation of the transistor.

Mr. Kenney then proceeded to describe the different types of transistor in use and their peculiarities. This led naturally to a discussion of the advantages and disadvantages of each type which, in turn, introduced the applications and limitations of the transistor. The effect that the transistor has had and will have on the design and application of the equipment in which it is used was then explored.

Future use of the transistor depends to a large extent on the development of improved production methods; however, its development should not be considered at a standstill. Mr. Kenney described the various production techniques which have been developed. His description of future possibilities in this regard was reminiscent of the development of titanium as a useful metal. One could not help but consider the manner in which the production and industrial engineers are invading fields which were, but a few years ago, the sole prerogative of the research scientist.

Paying tribute to our speaker, W/C J. W. McNee commended him on his grasp of the subject and the pleasant manner in which he had held our attention throughout his talk.

In a departure from our usual practice, the subsequent discussion was sparked by the use of a panel, consisting of Mr. A. Ramsay, Service Engineer, A.E.P.L., Chairman of the panel, Mr. H. Corbett, Radio Engineer, C.P.A.L., and Mr. Kenney. The discussion laid emphasis on the temperature limitations of the transistor, particularly in aircraft applications, and on the relationship of the vacuum tube and transistor. Concerning the latter, discussion centred on the maintenance aspect of the equipment in which the components were used. This form of discussion left everyone with the impression that we would be well advised to make proper use of the "panel" or "clinic" principle in future.

The meeting adjourned at 22.30 hours.

Edmonton—Reported by H. E. Davenport

June Meeting

The June meeting of the Edmonton Branch was held in the Auxiliary Officers' Mess, R.C.A.F., on Tuesday, June 12th. W/C J. G. Portlock, Branch Chairman, presided.

After the business meeting, S/L Diack introduced the speaker, Mr. J. A. Gillies, Chief Engineer, Canadian Pacific Air Lines, Ltd., who had chosen as his subject, "Commercial Aircraft Operations".

The general theme of Mr. Gillies' speech was engineering as related to passenger comfort and was thus quite different from the average subject. Mr. Gillies described how storage and other utility space was inadequate in modern long range aircraft. Provision had not been made by the manufacturer for the stowage of the numerous items necessary for overseas and other long distance flights, thus introducing the problem of keeping passenger accommodation clean and shipshape during a long journey. Food catering, Mr. Gillies explained, was the big problem. Trying to engineer a galley of adequate proportions together with its gadgetry of heaters and refrigerating system into an absolute minimum of space (dictated by the economics of passenger miles) was a problem of no mean proportions. Passenger seats, Mr. Gillies said, have given a considerable amount of trouble through mechanical failures and other causes, such as twisting of the structure to a point where it would not properly operate to its various adjustable positions. This appeared to be a continuing problem that is being tackled by both the airlines and the manufacturer.

Mr. Gillies cited several amusing instances of the ability of passengers to deform and seriously damage various items of passenger equipment that defied engineering skill to prevent. Simulation of these failures in the shop required a force and manipulation not usually associated with homo sapiens.

Mr. Gillies thought that the numerous problems related to passenger comfort, and particularly that of stowage, were engineering problems that should be met by both the airlines and the aircraft manufacturer jointly in the design stage. Members and guests enjoyed this little publicized aspect of engineering.

At the conclusion of the talk, Mr. Gillies showed two general interest motion pictures which concluded an interesting and successful meeting.

Cold Lake—Reported by R. W. Ellard

June Meeting

The C.A.I. members at Cold Lake held a meeting on the 20th June at 8.00 p.m. in the Airwomen's old canteen. In the absence of S/L R. G. Christie, Mr. J. Harrop presided.

After a business session, at which various matters concerning the organization of the Branch were discussed, Mr. Harrop called upon Mr. D. L. Wallis to introduce the speaker of the evening, S/L J. Collins, Chief Project Engineer of CEPE-AAED. S/L Collins' subject was Air Armament Evaluation.

S/L Collins traced the development of the need for armament evaluation in the R.C.A.F., culminating in the formation of the Air Armament Evaluation Detachment, and of course, R.C.A.F. Cold Lake and its firing range.

He explained the reasons for the shift from the curve of pursuit type attack used in the last war to the present lead collision course type of attack in current use.

S/L Collins gave a brief summary of some of the AAED's problems, as far as security restrictions would allow, and ended up with a question period.

The speaker was thanked by Mr. Harrop and after a general discussion and refreshments, the meeting closed at 10.30 p.m. There were 16 members present.

MEMBERS

NEWS

G. H. Dowty, Hon. F.C.A.I., was made a Knight Bachelor in the Birthday Honours last June.

T. E. Stephenson, F.C.A.I., President, has left the Department of Defence Production, of which he was Director of the Aircraft Branch, and has joined Canadian Pratt & Whitney Aircraft Co. Ltd. as Sales Engineering and Service Manager.

W/C E. P. Bridgeland, A.F.C.A.I., has been appointed Officer Commanding, R.C.A.F. Technical Services Detachment, A. V. Roe Canada Ltd., at Malton.

W/C J. N. Brough, A.F.C.A.I., Past Chairman of the Toronto Branch and formerly Officer Commanding R.C.A.F. Technical Services Detachment, A. V. Roe Canada Ltd., has been transferred to the R.C.A.F. Staff College, Toronto.

R. F. Hunt, A.F.C.A.I., on returning to England recently, has been appointed to the Board of directors of the parent Dowty Group Ltd. He continues as Director, President of Dowty Equipment of Canada Ltd.

C. D. Long, A.F.C.A.I., has left the National Research Council to join the staff of Spartan Air Services Ltd. in the Development Engineering Department.

J. S. Collins, M.C.A.I., has left Lucas-Rotax Ltd. and joined the Design and Development Group, Aeronautical Division, Minneapolis-Honeywell Regulator Co., Ltd., Leaside.

R. Carter Guest, M.C.A.I., who was Councillor for the Winnipeg Branch in 1955-56 until his retirement in December, has been appointed Special Representative to the President, Canadian Pacific Air Lines, Ltd., Vancouver.

S/L H. R. Janes, M.C.A.I., has been posted to England where he is attending the College of Aeronautics, Cranfield.

G. Milner, M.C.A.I., previously with Trans-Canada Air Lines, has joined the Planning Department of Bristol Aircraft (Western) Ltd., Winnipeg.

B. Towler, M.C.A.I., has left the Flight Research Section, N.A.E., and taken an appointment with the Boeing Airplane Company.

D. A. Clunis, Student, graduated from the University of Toronto in May 1956 and is now employed by the Ford Motor Co. of Canada, Ltd., Windsor.

F. H. Devereux, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by Canadair Ltd., Montreal.

F. L. Gilbertson, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by Avro Aircraft Ltd., Toronto.

G. W. Grover, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by Avro Aircraft Ltd., Toronto.

R. C. Isaac, Student, graduated from the Institute of Technology and Art, Calgary, in May, 1956, and is now employed by Canadair Ltd., Montreal.

W. A. Jones, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by Canadair Ltd., Montreal.

C. S. Melander, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by Canadair Ltd., Montreal.

G. S. Moyer, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by the Royal Canadian Navy.

R. J. Simone, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by Canadair Ltd., Montreal.

S. Singer, Student, graduated from the University of Toronto in May 1956 and is now employed by Avro Aircraft Ltd., Toronto.

R. H. Skeldon, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by Avro Aircraft Ltd., Toronto.

R. J. St. Cyr, Student, graduated from the Institute of Technology and Art, Calgary, in May 1956, and is now employed by Canadair Ltd., Montreal.

M. R. Subotincic, Student, graduated from the University of Toronto in May, 1956, and is now employed by the DeHavilland Aircraft of Canada, Ltd., Downsview.

DEATH

It is with deep regret that we announce the death of **Donald Fraser, A.F.C.A.I.,** Senior Research Officer, National Research Council. Many members will remember Mr. Fraser's short article entitled "A Spray Rig for Helicopter Icing Tests" in the May 1955 issue of the Canadian Aeronautical Journal.

ADMISSIONS

At at meeting of the Council, held on 11th July, 1956, the following were admitted to the grades of membership shown.

Associate Fellow

D. B. Bates, (on transfer from Member).

J. L. Brisley, Supervisor Engineering Staff Administration, Orenda Engines Ltd.: *29 Pamcrest Dr., Willowdale, Ont.*

R. Farmer, Engineer, Aircraft Component Design, Canadair Ltd.: *1475 Dutrisac St., No. 5, Ville St. Laurent, Montreal 9, P.Q.*

G/C J. R. Frizzle, (on transfer from Member).

W/C H. K. Hollingsworth, Airborne Armament Engineering Liaison, Canadian Joint Staff, 2450 Massachusetts Ave., N.W., Washington, D.C.

R. Insley, Chief Product Engineer, Ford Motor Co., 7401 So. Cicero Ave., Chicago 29, Ill.

J. P. Laviolette, Chief Compressor Design Engineer, Orenda Engines Ltd.: *126 Arundel Ave., Toronto 6, Ont.*

J. S. Parsons, Technical Director and Chief Engineer, Computing Devices of Canada, Ltd., P.O. Box 508, Ottawa 4, Ont.

P. E. A. Talbot, Technical Sales and Service Manager (Canada), S. Smith and Sons (Canada) Ltd., Box 96, Stn. H, Toronto 13, Ont.

C. Tilgner, Jr., Chief Aeronautical Engineer, Grumman Aircraft Engineering Corp., Bethpage, N.Y.

G. D. Watson, Director, Weapons Research, Defence Research Board: *2086 Fairbank Ave., Ottawa, Ont.*

G/C F. R. West, R.C.A.F. Station, Camp Borden, Ont.

Member

F/L J. L. Adamson, Quality Control Inspection, Air Materiel Command, R.C.A.F. Station, Rockcliffe, Ont.

W. C. Barlow, Chief Draftsman, Orenda Engines Ltd.: *47 Charleswood Dr., Downsview, Ont.*

A. E. Beckley, Project Supervisor Engineering, Avro Aircraft Ltd.: *Box 406, Streetsville, Ont.*

C. N. Bell, (on transfer from Technical Member).

G. T. Blanchard, Production Control Manager, DeHavilland Aircraft of Canada Ltd., Postal Station L, Toronto, Ont.

C. C. Bogart, Chief, Air Traffic Control, Air Services Branch, Dept. of Transport: *14 Rockcliffe Way, Ottawa 2. Ont.*

H. Brinkmann, Flight Test Engineer, DeHavilland Aircraft of Canada Ltd.: *777 Millwood Rd., Leaside, Toronto, Ont.*

E. J. Burn, Service Analyst, Avro Aircraft Ltd.: *2135 Avenue Rd., Apt. 310, Toronto, Ont.*

A. Caplan, Design Draftsman, DeHavilland Aircraft of Canada Ltd.: *145 Northcliffe Blvd., Toronto, Ont.*

J. R. Combley, Flight Test Engineer, Avro Aircraft Ltd.: *Officers' Mess, M.P.O. 503, Grande Centre, Alta.*

J. A. Conway, Designer Special Projects, Avro Aircraft Ltd.: *156 Watson Ave., Toronto 9, Ont.*

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MEMBERSHIP OF THE C.A.I.

as at the Meeting of the Executive Committee of the Council on the 27th August, 1956.

Technical	**1,573**
Associate	**65**
Total	**1,638**

The Technical grades comprise the following:

Honorary Fellows	11
Fellows	24
Associate Fellows	191
Members	794
Technical Members	425
Technicians	31
Students	97

SUSTAINING MEMBERS

Avro Aircraft Ltd. has now introduced into operation its big new hydraulic rubber pad forming press having an operating pressure of 15,000 tons. Designed and manufactured by the Siempelkamp Company of Germany to Avro Aircraft requirements, the new press will speed production of parts for the CF-105, Avro's new supersonic delta-wing fighter.

It can mould much thicker sheets of metal and is more efficient in the production of lighter metal parts than the 5,000 ton rubber pad press now used by Avro. It is also very fast, going through its complete cycle of operation in one minute.

An unusual feature of the new press is that the whole pressure is exerted from below, forcing the loading table up into the rubber pad. Most presses exert pressure downwards. Also of interest is the frame construction which is made up of metal "wafers" in groups of six. Each wafer weighs ten tons. About 20 ft of the press is below floor level and the foundations go down 38 ft.

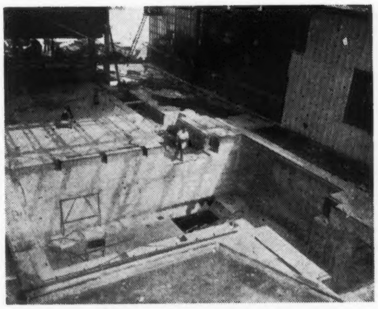
The 10 ft by 5 ft pad weighing 3,686 lb was specially manufactured by Goodyear. Some 1,600 gals of oil are required to operate the hydraulics system.

Technical details are as follows:

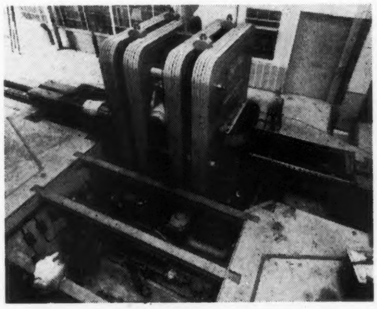
Total weight of press–600 tons
Total pressure–15,000 tons
Stroke–19 inches
Oil pressure–5,700 psi
Size of rubber pad–120" × 60" × 12"
Pressure on pad–4,000 psi

The press is constructed in frame design. The main cylinder operates vertically. The fast advance stroke is made by a 500 ton cylinder in the centre of the press. A big oil tank under a continuous 30 lb pressure allows the fast advance speed. Four pull-back cylinders located on the side of the main cylinder make the fast return stroke. A hydraulic equalizing device allows for any eccentric load on the loading table even under the maximum pressure.

Two loading tables, one on each side of the press, are hydraulically operated with high speed and cushion slow-down for both directions. It is the first press which has a hydraulically operated packing-change device. All important guides and bearings are connected to a pressure greasing system.



Press foundations



Installing ancillary equipment

Installing rubber pad

Avro's new press in operation

Orenda Engines Ltd.'s new engine, formerly known as the PS-13, has been named the Iroquois.

DeHavilland Aircraft of Canada Ltd. has introduced a modification to the Otter flap control system, in the light of the findings of an enquiry into an accident at Goose Bay on the 10th April last. The evidence, sifted and analysed by a group of deHavilland Canada engineers conducting the enquiry, has proved that the accident was caused by a sudden flap retraction when the flap selector was selected up while the aircraft was trimmed for full flap down, high speed. The resultant out-of-trim condition can produce a rapid nose down pitch of the aircraft resulting in negative overload conditions which may develop beyond the structural limits of any normal category aeroplane. In the case under investigation, the nose down pitch was not checked before the rapid build-up of stick forces developed, due to the element of surprise.

The inadvertent flap retraction was due to the ball in the up side of the check valve becoming jammed in the open position owing to the presence of foreign matter in the hydraulic system. Immediately the flap selector was selected up, the flaps retracted in a matter of aproximately 2 seconds.

To prevent any future repetition of inadvertent flap retraction, several new features are being introduced into the flap system by deHavillands. The first consists of a filter which will prevent any foreign matter from getting into the system. The second is a new cylinder head for the flap jack which will contain the present check valve and, in addition, a new irreversible valve especially designed to be impervious to foreign matter. Both these valves will be protected by isolating filters.

Some idea of the tremendous task which faced those responsible for determining the cause of this accident may be gleaned from the records of deHavilland's Photographic Department alone. During the investigation, some 2,200 photographs were produced. 2,100 ft of film and 5,000 ft of oscillogram recording film was used during the flight trials. Photographs were made of all the structural static tests and over 1,500 ft of film were taken in the air to record flight manoeuvres during aerodynamic trials. In addition to some 40 members of the

engineering staff of the deHavilland Aircraft of Canada, the team conducting the investigation included experts from the RCAF, DOT, NRC, USAF, US Army, NACA (US) and the RAE (England).

During the early stages of investigation, exhaustive tests of the Otter structure were carried out. These revealed that the Otter airframe is exceptionally strong in all respects and capable of withstanding load factors far in excess of international airworthiness requirements.

The wing, for example, is required by US authorities to develop a negative bending load factor of -1.4 g in normal flight and an ultimate, or breaking load factor, of 2.1 g in the normal category. Under an actual test to destruction at 8,000 lb gross weight, the wing failed in negative bending at a load factor of -2.6g. This is 125% of the required ultimate load factor and 185% of the normal load factor of inverted flight.

A series of flight trials was held in which the Otter was subjected to a punishing ordeal of abnormal flying manoeuvres. This phase of the investigation established the fact that the aircraft has absolutely no unusual or dangerous flying characteristics of any kind whatsoever.

During the course of the investigation an intensive study was made of the records of many Otters at present in service. This revealed that some have completed over 3,000 trouble-free hours of flying time under operating conditions as severe as any that aircraft are ever likely to be called upon to survive. It was estimated that Otters in operation have a total of approximately 75,000 hours of accumulated flying time.

PSC Applied Research Ltd. report that their airborne profile recorder or APR, a Canadian-developed electronic aerial survey device, was featured at the International Congress of Photogrammetry in Stockholm, Sweden, July 17-26. It has been used extensively in mapping remote areas of Canada in recent years. Also featured were the Gamble plotter, a new Canadian map-making machine that is expected to save 30% of the time required to draw contour maps; a special high-speed tri-film processor developed for the RCAF and other users; and a new type of aerial positioning camera. All these pieces of equipment were developed in Canada for aerial photography and map-making, a field in which Canada has acknowledged leadership. This is the first time any of these pieces of equipment have been shown abroad.

Mr. T. U. Blachut, of the National Research Council's photogrammetric research staff at Ottawa, gave a technical paper on the APR at the Congress to the world's leading photogrammetrists. NRC started development of the APR in 1947. The equipment combines a highly accurate radar altimeter to measure the terrain clearance and a very sensitive pressure altimeter to measure variation in aircraft flying height above sea level. Many changes have been made by the Photographic Survey Corporation in the original NRC design of the APR, as a result of experience with the equipment on actual mapping operations. The latest model will be ready for production soon and features greatly reduced size and weight. Accuracy and operational convenience have been markedly improved. Accuracy of $\pm$ 5 ft in the clearance from a height of 30,000 ft has been attained and the sensitive altimeter, which is free of acceleration effects, has demonstrated a sensitivity of less than 1 ft.

The Gamble plotter was invented by Mr. S. G. Gamble, Chief Topographical Engineer, Department of Mines and Technical Surveys. The first application of Mr. Gamble's principle was seen in the engineering model designed for use with standard multiplex plotting equipment. The production version incorporates either the Bausch and Lomb Multiplex or the ER55 Balplex projector system. (Williamson Multiplex projectors can be used by substituting a special projector bar and rack for the standard type.)

In normal multiplex, a disc containing an illuminated spot and attached to a small tracing table is raised to the desired elevation; the operator then moves the tracing table about on his plotting sheet by hand, keeping the illuminated spot just touching the apparent position of the ground, in order to trace the elevation or contour line.

The Type T301 Mk 2 Gamble Stereo Plotter makes use of a 10″ diameter projected pattern of dots which forms a reference plane on the surface of a 38″ × 38″ tracing table. The dot projector, which is a small self-contained unit, may be placed in any desired position on the table surface. By means of an electrical drive and finger tip control adjustable to any convenient position over the working surface, the projector system can be raised or lowered through a distance of 250 mm in the vertical direction, causing the stereo model to rise or fall through the reference plane of the projected dots. This adjustment can be made within the accuracy of 0.1 mm.

The elevator setting is easily seen on a 100 mm optical scale divided into 0.1 mm divisions and projected on a ground glass screen. (Other scales may be substituted as required and each scale is adjustable for any position throughout the 250 mm travel.) When the model has been set at any chosen elevation with reference to the dot pattern, the operator can trace the contour line freehand.

A separate blower unit is provided to supply cooling air to the model projectors and dot projector.

While all advantages of the new system have not yet been explored fully, it is already apparent that speed is increased with this type of operation. As compared with existing methods, the operator tends to trace a smoother series of contours through being able to anticipate to some extent the "lie" of the land ahead of his pencil. This gives a better and more graphic representation of the form of the terrain.

PSC Applied Research also announce two important contributions which they are making to the International Geophysical Year in 1957. One of these is the Auroral Recorder, for measuring the Aurora Borealis, and the other is the Station Magnetometer, for measuring the three orthogonal components of the earth's magnetic field.

The Type T609 Auroral Recorder, developed by Dr. D. Hunten, University of Saskatchewan, and produced by PSC Applied Research Ltd., is an instrument designed to produce a photoelectric recording of auroral phenomena. The tabulated results are obtained directly in the form of a punched tape and indicate the brightness of the auroral display and the position on a particular meridian in the sky. The punched tape output also indicates the time of measurement of the phenomena and the presence of cloud or haze which might tend to obscure the aurora.

The Auroral Recorder consists of two major units, a scanning head and an amplifier assembly. The scanning head is provided with an optical system which permits step scanning a meridian of the sky from the southern to the northern horizons, during a five minute cycle. A sensitive photo-multiplier tube and selective interference type filter, permitting only a response at 5577 A°, is also mounted in the head assembly. A cathode follower output tube permits coupling to a low impedance cable. Provision is also made for a photoelectric interlock to automatically turn the equipment on and off at sunset and sunrise.

The amplifier assembly, which may be mounted in a standard relay rack, has been designed in modular form for ease in servicing and maintenance. These modules are identified by circuit function and consist of power supply units, amplifiers, detector and a discriminator. The circuits are arranged to actuate relays for each level of brightness which

irradiates the photo-multiplier—the intensity recorded being an integrated value over a fifteen second interval.

The equipment has been designed to good commercial design standards; the head assembly which operates outside has been designed to withstand a wide range of environmental conditions.

The output of the Auroral Recorder may directly operate a recording type milliam-meter as well as a teletype tape printer, which produces a record of the auroral brightness in the form of a prearranged code on a paper tape.

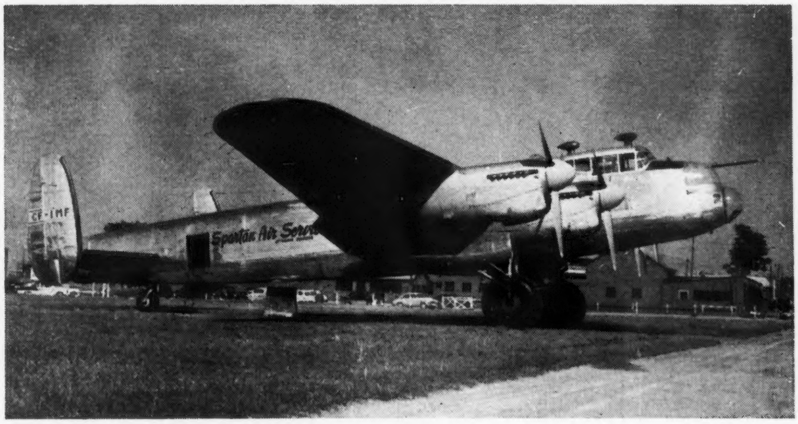
A calibrator has also been designed for use with this instrument to provide different values of brightness at the wavelength of the aurora.

Designed by Dr. P. Serson of the Dominion Observatory, the magnetometer consists of three assemblies—a remote detecting head, an oscillator-amplifier assembly and a regulated power supply. In addition, three recording type meters are required. The instrument has a sensitivity of 1,000 gammas full scale (1 gamma equals 10-5 oersted) and the sensitivity may be varied by changing a plug-in feedback network in the amplifier, or by using a recording meter of different sensitivity. A magnetic field component may be recorded by more than one meter at different sensitivities.

The detecting head, which may be levelled, consists of the three orthogonal flux gate detecting coils enclosed in a polyester fibreglas cover. Particular care has been taken in the design to ensure a firm mechanical assembly. Materials used in the head have been selected for freedom of magnetic properties and have been finished to avoid deterioration due to corrosion.

The amplifier assembly, which may be mounted in a standard relay rack, has been designed in modular form; each of the component amplifiers may be plugged into the rack assembly. This method of construction permits rapid interchange of units for service and maintenance and, with spare modules, permits uninterrupted use of the equipment.

The regulated power supply unit also mounts on a relay rack panel and is supplied with cables to the other assemblies.



Spartan's Lancaster

Spartan Air Services Ltd.'s Lancaster left Ottawa in June on a new mapping operation over the far north. An area of 150,000 sq miles will be covered with Shoran controlled aerial photography by Spartan Air Services Ltd. and Canadian Aero Service Ltd. for the Army Survey Establishment of the Department of National Defence.

Shoran, an electronic plane-positioning device developed during World War II to guide bombers over a target, is now used to make geodetic measurements in large and mostly inaccessible areas. Based upon the principle of aerotrilateration, Shoran has proven a valid, economical method of providing horizontal control for aerial photography.

During May, while the Lancaster was being outfitted with the special Shoran gear in Ottawa, an initial survey party, using a Norseman and Bristol Air Freighter, established ten Shoran ground stations between Pelly Lake, 600 miles northwest of Churchill, and Coral Harbour. These stations will receive and transmit the Shoran signals which guide the survey plane and provide the geodetic control. Two men operate each station throughout the summer, completely isolated except for the occasional supply flight and their radio.

The Lancaster is one of three purchased by the Canadian survey company this spring and it is the first Lancaster to be owned and operated by a private firm. Spartan officials say the aircraft's long range and good stability make it the ideal aircraft for this type of operation.

Airborne surveyors call this survey one of the most challenging geodetic assignments anywhere in the world. Over twelve months of planning and organization go into the operation that depends upon one week of perfect weather for aerial photography, but clear cloudless days in the Canadian Arctic are few. Other major operational problems are the fifty mile per hour winds that lash the 60 ft Shoran masts, the 20 below zero temperatures and an air lift of 300 tons of supplies.

This is the fifth consecutive year of far northern mapping to be carried out by Spartan and Canadian Aero. Together, they have surveyed more than 500,000 sq miles.

Computing Devices of Canada Ltd., opened their new plant at Bells Corners, one mile west of Ottawa, on the 15th June. The new plant covers 82,000 sq ft and provides for a 75,000 sq ft extension which will be ready in 1957. Electronics and instrument laboratories, model shop, electrical test and assembly shops, machine shop and Canada's first privately owned data processing centre, formerly housed in three separate parts of Ottawa, have been brought together into this new facility.

The company's specialized efforts are directed mainly in the fields of aircraft instrumentation, electronic computors, data processing, automatic control of manned and unmanned vehicles, as well as automatic control of machine tools and manufacturing processes. Typical of its work is the development of the P.H.I. and the complex navigation equipment for the CL-28.

The new plant was opened by Mr. D. A. Golden.

BOOKS

The Analysis of Structures. By N. J. Hoff. John Wiley and Sons, 1956. 493 pages. Illus. $9.50.

Dr. Hoff is a man whose diversified interests in the field of engineering mechanics give him a more than ordinarily clear insight into the variety of problems which the practising structures engineer may meet. He has also been faced with the task of imparting a sufficiently broad competence in graduating engineers to meet those problems. The Hoffian approach is one which can only be met with approval—the elucidation of the minimum number of principles required to solve the maximum number of problems.

A consolidation of lecture notes for a first-year graduate course, "The Analysis of Structures" is written in textbook form, each of its four subdivisions being more or less self-contained with illustrative examples and test problems. Starting with a thorough explanation of the principle of virtual displacements, the first part introduces frameworks with redundancies and, in particular, the Hardy Cross moment-distribution method of anlaysis. In the second part, the initial principle is broadened and strengthened by the introduction of strain energy and minimal principles. A treatment of the calculation of buckling loads, particularly of columns under various conditions, then follows and part four concludes with a presentation of the complementary energy and least work methods applied to limit load analysis and analysis of reinforced monocque shells.

Dr. Hoff has written an interesting and useful textbook which should find favour with both lecturers and students.

A. H. Hall

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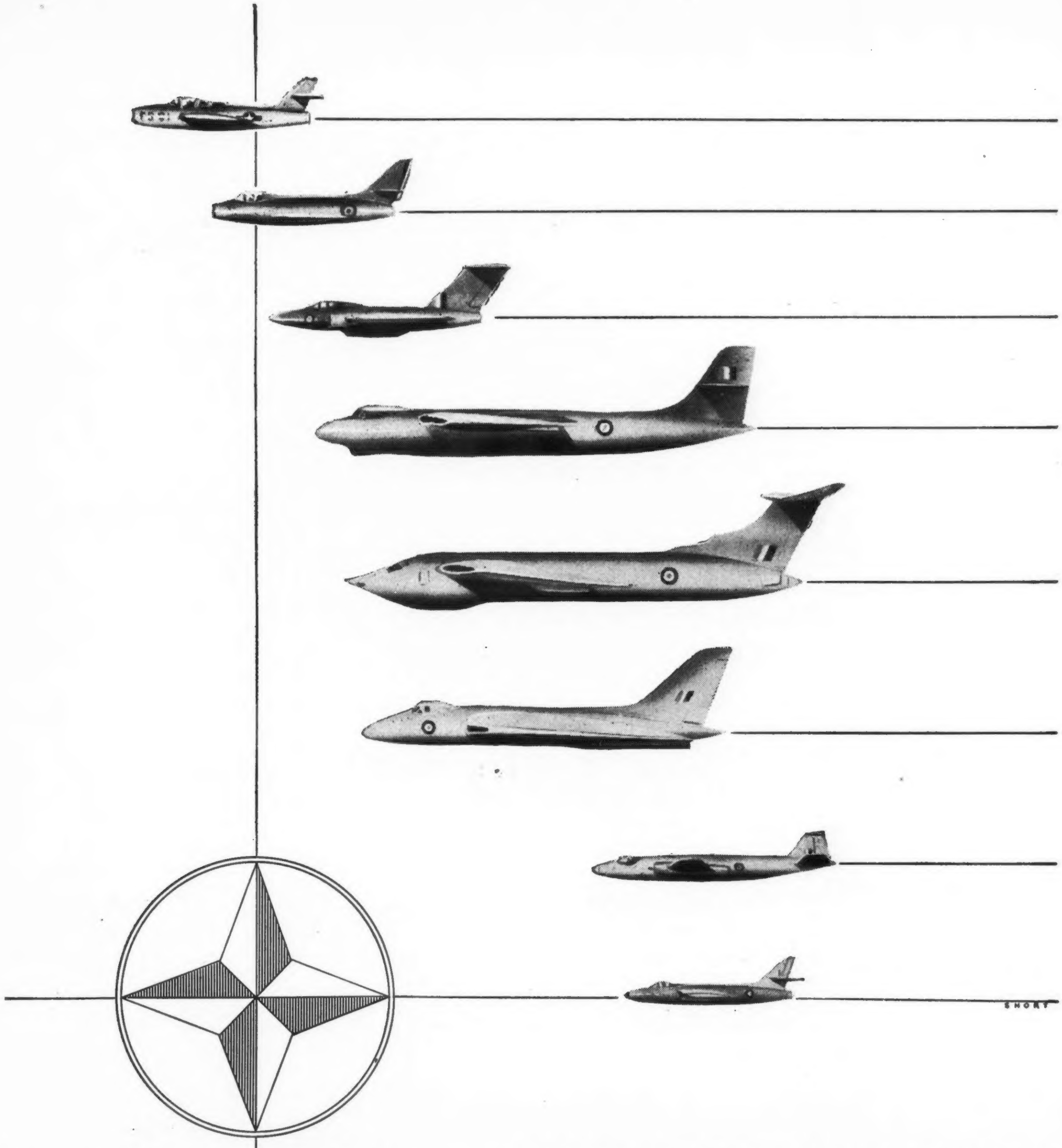

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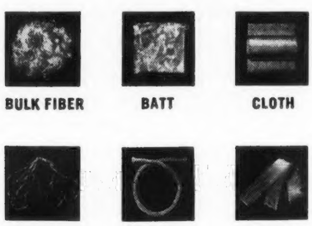

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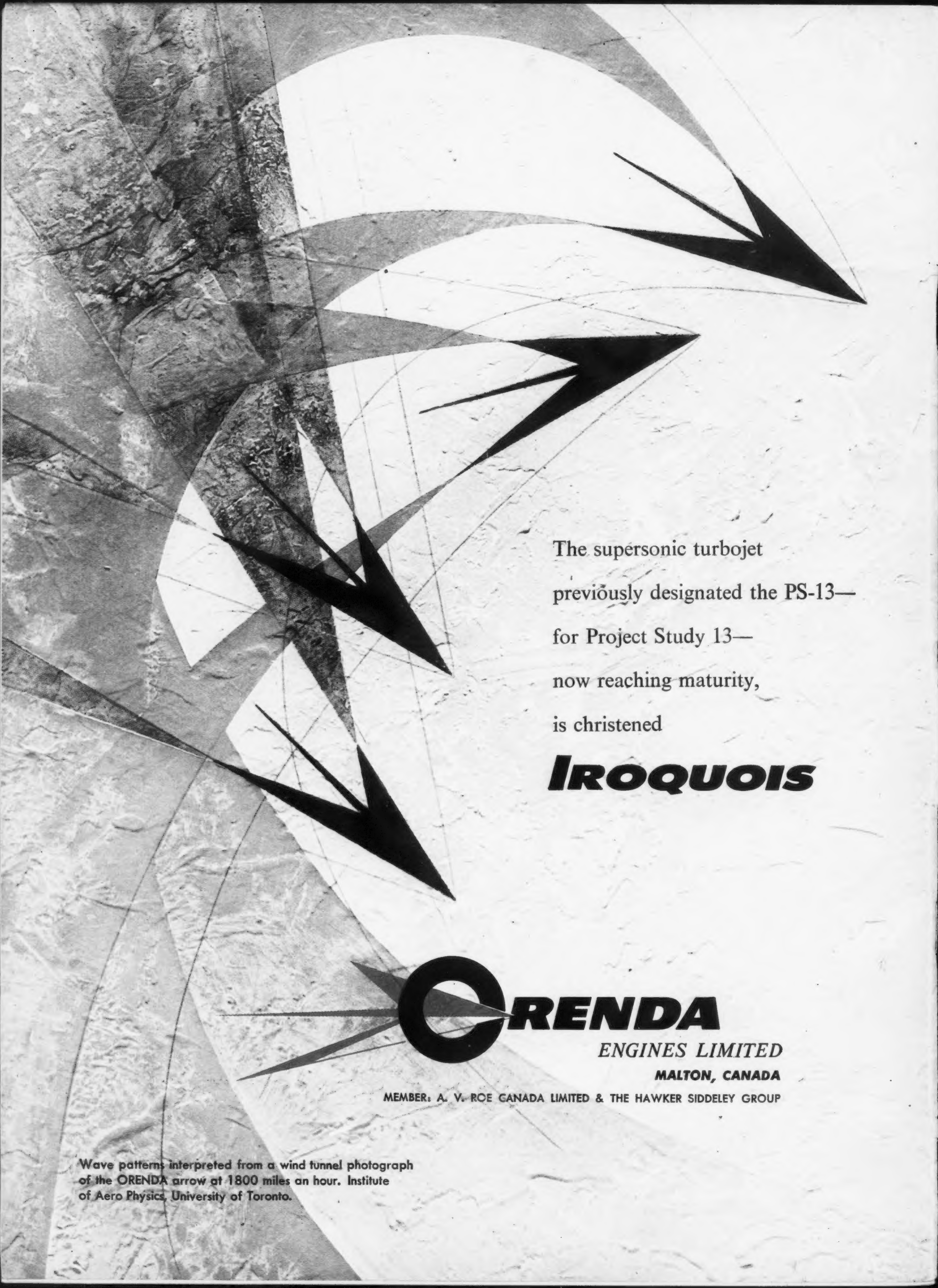
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